COAI

RSM/COAI/2015/058

April 24, 2015

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Sub: COAI Response to the TRAI Consultation Paper on "Regulatory Framework for Over-the-top (OTT) services"

Dear Sir,

This is with reference to the TRAI consultation paper on "Regulatory Framework for Over-the-top (OTT) services" issued on March 27, 2015.

In this regard, please find enclosed COAI's submission to the said consultation paper as Annexure – 1. Further, please find enclosed:

a. Paper titled, "Network Neutrality orInternet Innovation?" by Mr. Christopher S. Yoo , University of Pennsylvania Law School as Annexure – 2.
b. Paper titled, "The FCC's "Net Neutrality" rules are technically unworkable by Martin Geddes" as Annexure – 3.
c. Paper tilted, "Net Neutrality and Technical Challenges of Mobile Broadband Networks by Dr. Jeffrey H. Reed and Dr. Nishith D. Tripathi" as Annexure – 4.

We believe that our submission will merit your kind consideration.

Thanking You

Sincerely yours,

Rajan S. Mathews

Rajan S. Mathews
Director General

CC : Dr. Rahul Khullar, Chairman
: Dr. Vijayalakshmy K Gupta, Member, TRAI
: Dr. Anil Kaushal, Member, TRAI
: Shri. Sudhir Gupta, Secretary, TRAI

COAI Response to TRAI Consultation Paper
On
Regulatory Framework for Over-the-top (OTT) services

Released on March 27, 2015

PREAMBLE

1. COAI is committed towards connecting the 1 Billion Unconnected Citizens of India and we welcome TRAI's Consultation Paper On Regulatory Framework for Over-the-top (OTT) services.

2. COAI fully supports the digital India vision of the government and suggests adoption of policies and promoting ecosystem which enables fulfillment of this vision. It is important that the Regulatory framework adopted is pro choice, pro poor, pro innovation and is hence pro India.

3. In this regard, we wish to submit that while we acknowledge the role of OTT players, however, it is pertinent to note that some of the services that are offered by the OTT players such as messaging/instant messaging and VOIP telephony are perfect substitutes of the services that are being offered by the TSPs under UASL/UL.

4. There is thus a need to address the various regulatory imbalances and ensure **Regulatory Neutrality**. For this, the Authority should apply the principle of, "Same services, Same rules". Only under such an environment, the TSPs will get a fair chance to compete with OTTs on similar pricing and terms.

5. We, therefore, believe that companies should be free to pursue commercial agreements which offer consumers innovative new content and services underpinned by new business models.

6. The issue of net neutrality is a complex issue that is being debated in several countries all over the world and administrations are looking for the right solution to ensure the continued growth of the internet whilst managing the unique challenges of a mobile environment, where capacity is finite due to limited availability of spectrum and huge investments are required to sustain the growth of internet traffic. Operators have to manage their resources and capacity to ensure the best possible customer experience.

7. **We hereby state that the Industry Supports Net Neutrality and seeks for Net Equality. We support free and open internet for all.**

8. Net Neutrality should be looked at from the holistic framework of Internet Governance. There are multiple approaches to look at net neutrality and there are various definitions of the subject depending on:

   i) Whether they reflect what the consumer is supposed to do versus what the providers of the network are prohibited from doing, and
   ii) Whether they seek to broadly limit differentiated treatment in general versus a more limited restriction on harmful or anticompetitive discrimination.

9. Keeping in view the great complexity of technical, economic and policy-related issues that Net Neutrality involves, pinning down a precise definition of net neutrality is difficult. One of the most balanced perspective in defining Net Neutrality is as given below:

   "No denial of access and absence of unreasonable discrimination on the part of network operators in transmitting internet traffic."

10. India is a market where the complete country still does not have the benefit of mobile or broadband coverage. **The immediate priority in India, where 80% of the population has no data connectivity, is for rolling out broadband networks, rather than continue to debate on the concepts and issues of Net Neutrality which are only beginning to be defined globally. It is high time we prioritize the connectivity for all the villages of India as envisaged in the Digital India programme.**

11. The Government is targeting to connect all village local bodies (Panchayats) by broadband internet and phones, promote e-governance, WiFi connectivity in 250K schools, universities; public hotspots for citizens. We understand that a budget of INR 70,000 crores till 2019 has also been approved for telecom & IT covering:

    - Enhanced expenditure on broadband network of INR 320 bn to connect 250k Village Panchayats.
    - INR 160 bn to provide mobile connectivity by 2018 to ~42,300 villages that presently have no network coverage.

12. Further, as per Planning Commission's 12th Five Year plan projections, the total investment in the Telecom sector, which is an infrastructure sector, is expected to be **Rs. 943,899 Cr** during the five year period and 93% of the total investment is expected to come from the private sector.

Projected Investment (in INR crore) in Telecommunications under 12th Five Year Plan

	2012-13	2013-14	2014-15	2015-16	2016-17	Total	%
Centre	15203	14827	14446	14023	13611	72110	7

Private	90746	121263	162042	216535	281203	871789	93
Total	105949	136090	176489	230557	294814	943899	100

13. Thus, we are of the view that our objective today is to connect a billion Indians who are not connected today. In order to achieve this, the internet must be made affordable. So, if the industry innovates to make the internet affordable for the millions of customers by getting businesses to pay for it – what better way to bridge the digital divide through business arrangements that subsidize end usage.

14. **The debate should therefore shift from net neutrality to – net equality and Internet for all.**

15. COAI therefore advocates connecting the 1 Billion Unconnected Citizens of India, under the ***"Sabka Internet, Sabka Vikas"*** initiative.

16. Further, in order to achieve Regulatory Neutrality, COAI advocates the principle of, "Same services, Same rules". Only under such an environment, the TSPs will get a fair chance to compete with OTTs on similar pricing and terms.

17. **The Industry is committed to an Open Internet, i.e.**

    a. Net neutrality - access should be made available to all.
    b. Bringing everyone on the internet – not just the privileged few.
    c. Freedom for end users to send or receive information and to use the services of their choice
    d. Access to all content and applications without discrimination
    e. No blocking of competing services
    f. Transparency - about what traffic management is taking place, to enable consumers to choose the type of service they want
    g. A level playing field – Net Neutrality and Net Equality
    h. Same regulatory and governing rules to be applied to all those offering the same service

Summary Submission:

Thus, we support Net Neutrality and seek Net Equality. **Net Equality means:**

a. Access to all content and applications without discrimination.

b. To bring everyone on the internet – not just the privileged few.

c. "Same services, Same rules".

ISSUE WISE SUBMISSIONS

Q1: Is it too early to establish a regulatory framework for OTT services, since internet penetration is still evolving, access speeds are generally low and there is limited coverage of high-speed broadband in the country? Or, should some beginning be made now with a regulatory framework that could be adapted to changes in the future? Please comment with justifications.

COAI Response

1) At the outset, we would like to submit that the **Sustainable OTT services are good for the telecom sector** and the Digital India Story. We would hereby like to submit that any policy which is framed by the government /regulator needs to create open and enabling Environment for both operators and OTTs to co-exist and grow.

2) While it is right to say that internet penetration is still evolving and is less than 20%, access speeds are generally low and there is limited coverage of high-speed broadband in the country, we need to acknowledge that the TSPs are already facing challenges due to the increased take-up and growth of OTT services.

3) While we welcome the entry of OTT players and believe that they play an important role and offer many new services; however, it is pertinent to note that some of the services that are offered by the OTT players such as messaging/instant messaging and VOIP telephony are perfect substitutes of the services that can be offered by the telcos under UASL/UL. These OTT players have rightly been classified by the Authority as "OTT Communication Services" players and their services are in direct competition with the licensed communication services offered by the TSPs. These services are cannibalizing the revenues of the licensed TSPs and this trend is expected to further accelerate in the coming years.

4) We would like to further submit that though the data network utilization due to these services increases the data revenue of the service operators, however the increase in data revenue is insufficient to compensate for the loss in revenues due to OTT services

5) It has been correctly pointed out by TRAI in its consultation paper that there are following repercussions due to the OTT services:

    - Regulatory Imbalances
    - Impact on the economy
    - Security Issues

6) The extensive and stringent security conditions laid down and required to be met by the licensed TSPs are not applicable to the OTT Communication players. The OTT players are not subject to the significant investment or any of the regulatory costs/taxes that have to be borne by the telcos.

7) The various regulatory imbalances between the TSPs and the OTT Communication players have been comprehensively brought out by the Authority in Para 3.4 of its Consultation Paper. The Authority has rightly noted that despite TSPs and OTTs providing similar services to consumers, the TSPs bear the cost of infrastructure, spectrum, and payment of license fees and spectrum usage charges, which are not applicable to the OTT Communication players. The TSPs also have the obligations related to rollout, meeting quality of service parameters and security related obligations. Many of these do not apply to OTT communication players, which results in an arbitrage opportunity.

8) Further, India needs substantial investment in infrastructure, particularly for the development of our broadband infrastructure. Without a parallel revenue stream to support these investments, the investment capability of the Telcos may suffer in India which is extremely undesirable. **This in turn is also resulting in a loss of revenues to the Government Exchequer, which forces them to continue to extract revenue from licensed TSPs.**

9) **Recommendation: In view of the above, we submit that the time is ripe for a comprehensive review to build a Regulatory Neutral, Forward Looking and Transparent framework under which both TSPs and OTT players thrive and which ensures "Same rules for Same services".**

Q2: Should the OTT players offering communication services (voice, messaging and video call services) through applications (resident either in the country or outside) be brought under the licensing regime? Please comment with justifications.

COAI Response

1) As highlighted by us in the preamble, we would like to submit that there is a need to ensure Regulatory Neutrality so that there is a level playing field for all the players that exist in the eco-system.

2) The Authority should apply the principle of, "Same services, same rules". We believe that only under such an environment, the TSPs will get a fair chance to compete with OTTs on similar pricing and terms.

3) **Recommendation: There is a need to build a Regulatory Neutral, Forward Looking and Transparent framework under which both TSPs and OTT players thrive and which ensures "Same rules for same services".**

Q3: Is the growth of OTT impacting the traditional revenue stream of TSPs? If so, is the increase in data revenues of the TSPs sufficient to compensate for this impact? Please comment with the reasons.

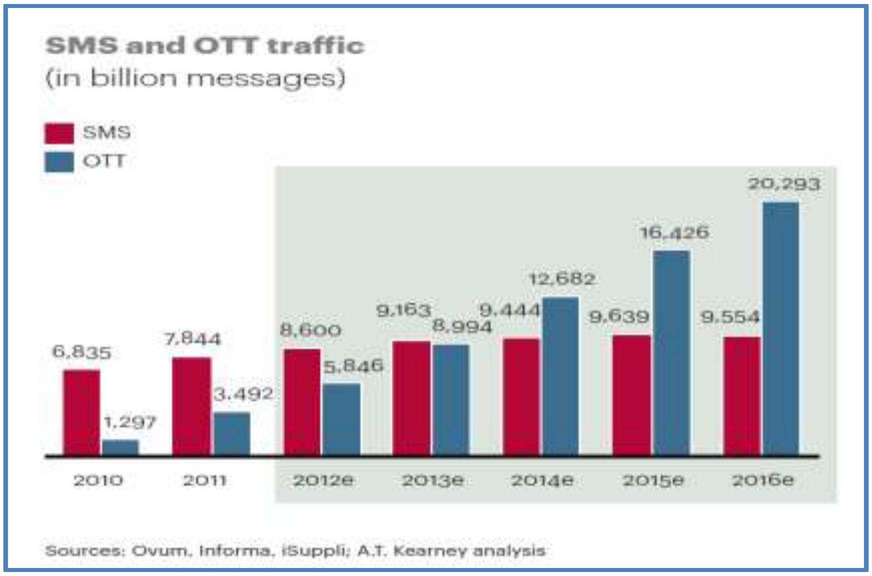
<u>COAI Response</u>

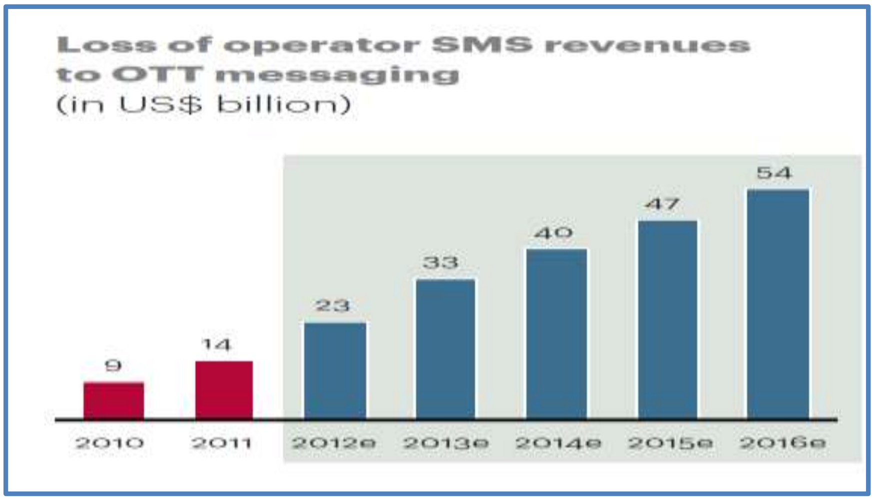
1) The growth of OTT communication services is impacting the traditional revenue streams of the TSPs. The growth in data revenues is insufficient to address this erosion. Going forward, with the increasing penetration of Smartphones, this trend will only accelerate, thus further adversely impacting the financial viability and business sustainability of the TSPs.

2) The implication of the revenue will be largely due to substitution of voice and messaging service

a. <u>Messaging substitution</u>

i. Instant messaging services and other social networking tools are affecting SMS revenues, and SMS is becoming less important for many consumers. In comparison to SMS traffic, which is likely to witness limited growth, OTT is expected to grow rapidly to 20.2 trillion messages. The success of the standalone messaging app is remarkable due to one simple factor: it is 'free'. The attraction of such services is bound to grow as integration improves.



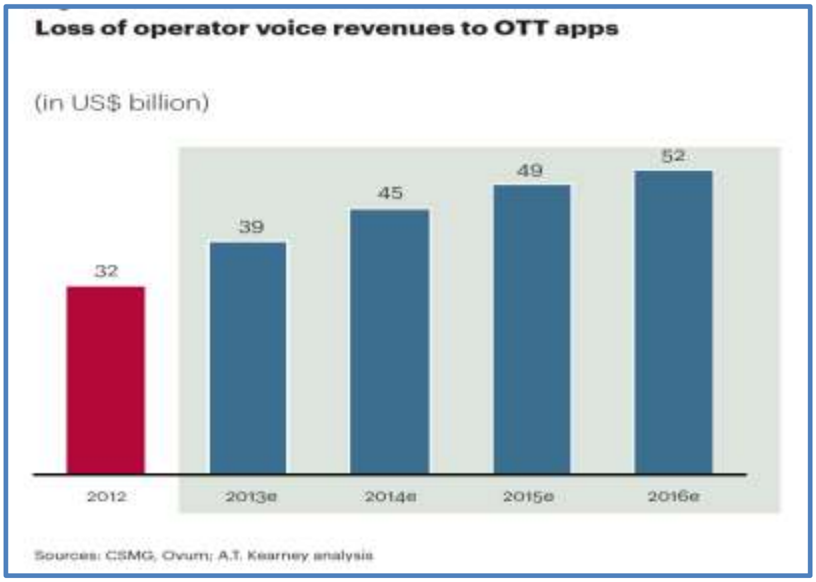


Source: Ovum, Informa, iSuppli, A.T. Kearney analysis

ii. As mobile Internet is steadily growing as a key revenue generator, SMS is slowly declining as a significant revenue opportunity. According to research firm Ovum, the Indian telecom industry lost close to USD 781 million in 2012 in SMS revenues due to the emergence of social messaging apps and OTT. Indian telecom operators may lose USD 3.1 billion in SMS revenues by 2016.

b. <u>Voice Substitution</u>

i. Voice revenues are expected to suffer because of VoIP-based OTT offerings. Several OTT players have already had an impact on mobile VoIP growth and on the total voice market.



ii. In India, 81.9% of revenues are generated by voice. So far, the impact of the stand-alone 'free' voice apps has been limited due to poor convenience and poor integration into the rest of the communications platform; within the next 2-4 years both would improve. Adoption will be further spurred by improvements in network quality that will support the user experience of these services.

3) Data revenues do not compensate for fall in revenues from OTT services

According to an industry research, the number of mobile operators generating revenues from OTT services by charging for data is falling year-on-year. In 2013, this figure was one-fifth, down from 26% the previous year, and 50% in 2011. TRAI has itself highlighted the fact increased data usage fails to compensate for loss of revenues to TSPs arising due to OTT services. Further, these services also put strain on the network, thus requiring further investments.

Q4: Should the OTT players pay for use of the TSPs network over and above data charges paid by consumers? If yes, what pricing options can be adopted? Could such options include prices based on bandwidth consumption? Can prices be used as a means of product/service differentiation? Please comment with justifications.

<u>COAI Response</u>

1) As highlighted above, increased data usage fails to compensate for loss of revenues to TSPs arising due to OTT services. Further, these services demand high speed networks

that require substantial investment in infrastructure, particularly for the development of our broadband infrastructure both from the fixed and mobile perspective.

2) It may also be noted that India is a market where 80% of the population still does not have the benefit of broadband coverage and only 7% of the subscribers are availing mobile broadband services as of February 2015.

3) The immediate priority in India, thus is to roll out broadband networks and significant investments would be required to be made by the mobile operators on spectrum, network and IT infrastructure and development of platforms and services over the next several years. Without a parallel revenue stream to support these investments, the business model will become unsustainable for telcos in the long run. Thus, we are of the view that there is need for making the telecom industry financially sustainable. Industry should be able to invest in growth of networks for fulfilling the digital India dream.

4) COAI hereby advocates for the Open and Pro-innovation Environment wherein pricing flexibility is provided to the operators and the choice is provided to the customers.

5) Thus, TSPs should be given the freedom to negotiate commercial arrangements with OTT players. The operators should be allowed to engage with the OTT players to get into the bilateral arrangements providing adequate measures for consumer protection.

6) The same will not only provide sustainable environment for the TSP's and OTT players, but will also help government in its various Priorities and goals for Communication Services such as:

   a. Digital India
   b. Broadband for All
   c. National Optic Fibre Network (NOFN)
   d. 100 Smart Cities
   e. M- Governance – Sabka Vikas
   f. Make in India

Q5: Do you agree that imbalances exist in the regulatory environment in the operation of OTT players? If so, what should be the framework to address these issues? How can the prevailing laws and regulations be applied to OTT players (who operate in the virtual world) and compliance enforced? What could be the impact on the economy? Please comment with justifications.

COAI Response

1) As correctly highlighted by TRAI in its Consultation Paper, there are regulatory imbalances which need to be addressed and the same are highlighted in detail below.

2) **Level Playing Field:** The services that are offered by the OTT communication players such as messaging/instant messaging and VOIP telephony are near perfect substitutes of the services that can be offered by the telcos under UASL/UL. There is a need to ensure a level playing field for all the players in the eco-system offering communication services.

3) **Licensing Compliances:** Presently, for OTT communication players in India, in respect of VOIP services, Internet telephony in India is governed by the ISP license. The license does not allow having PSTN/PLMN connectivity in India. Voice communication to and from a telephone connected to the PSTN / PLMN and following E.164 numbering is prohibited in India. OTTs are not required to acquire a license or register in India and have no obligation to provide any LI facility, QoS and emergency calling. We understand that the Home Ministry has decided that any service provider, which provides communication services in India via any media through VoIP should be mandated to be registered in India, having its office, server located in the country and therefore subject to Indian laws. Necessary provisions may be incorporated through amendment in the Indian Telegraph Act 1885 and IT ACT 2000.

4) **Telemarketing issues**: OTT apps are increasingly being used for tele-marketing activities flouting the guidelines and Regulations laid down by TRAI. TSPs have made significant investments in putting in place “Signature Verification” solutions to address the issue of telemarketing SMS. However, the telemarketers are now increasingly using OTT apps to send messages to subscribers. This is a clear breach of the TRAI Regulations and needs to be addressed.

5) **Regulatory Costs:** OTT communication players are not subject to any of the regulatory costs/taxes that have to be borne by the telcos. The telcos pay multiple levels, including regulatory levies, duties and taxes of over 30% of the Adjusted Gross Revenues as compared to just 5% for other Asian economies. The OTT players are able to ride on TSP’s network without being subject to any regulatory/license payments/restrictions. It is unclear what levies and taxes the OTT players pay, if any, in India, as compared to the licensed telecom players here.

6) **Quality of service norms:** Quality of services is becoming a major issue for OTTs as the network is choked with high bandwidth services such as HD videos, movie streaming, high quality web conferencing, etc. This is creating a challenge for both OTTs and operators, as operators are struggling to add capacity to their network and OTTs are falling short of user expectations on quality of service.

7) These regulatory imbalances need to be addressed on priority and the principle of same service same rules should be applied in respect of OTT communication services and traditional telephony services.

8) **Recommendation: In light of the above COAI advocates adoption of "Same rules for Same services".**

Q6: How should the security concerns be addressed with regard to OTT players providing communication services? What security conditions such as maintaining data records, logs etc. need to be mandated for such OTT players? And, how can compliance with these conditions be ensured if the applications of such OTT players reside outside the country? Please comment with justifications.

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Q7: How should the OTT players offering app services ensure security, safety and privacy of the consumer? How should they ensure protection of consumer interest? Please comment with justifications.

COAI Response

1) **Security Compliances:** At present, there is a widely differing treatment accorded between telcos and OTT players as regards security compliance requirements on similar services. It should be noted that extensive and stringent security conditions are laid down and required to be met by the licensed telcos. These include:

   a. Taking permission/approval of the licensor for any new service
   b. Setting up Lawful Interception and Monitoring (LIM) systems
   c. Restriction on switching of domestic calls/messaging from outside the country
   d. Restriction on sending user information abroad
   e. Gives the Licensor the right to inspect the sites/network used for extending the service
   f. Providing necessary facilities for continuous monitoring of the system, not employing any bulk encryption equipment; taking prior evaluation and approval of Licensor for any encryption equipment for specific requirements
   g. Switching/Routing of voice/messages in P2P scenario
   h. Responsibility for ensuring protection of privacy of communication and confidentiality of subscriber information
   i. Quality of Service, Unsolicited Commercial communications, Complaint Redressal Mechanism, etc.

2) The OTT players who use data access channel of the telcos to reach the customer with similar voice and messaging services are not subject to the security restrictions imposed on the telcos. There is undoubtedly a need to ensure that these concerns are addressed and there is level playing field between the TSPs and the OTT communication service providers.

3) This may be done by ensuring that the regulatory framework applicable to OTT communications services is the same as that applicable to the communications services provided by TSPs.

Q8: In what manner can the proposals for a regulatory framework for OTTs in India draw from those of ETNO, referred to in para 4.23 or the best practices summarised in para 4.29? And, what practices should be proscribed by regulatory fiat? Please comment with justifications.

COAI Response

1) At the outset, we submit that the "interconnection" framework proposed by ETNO is not suitable or relevant for OTT as interconnection, by its very nature entails peer-to-peer connectivity.

2) The OTT players are not peering with the TSPs, they are riding on the network created by the TSPs. Thus we believe that it will be wholly inappropriate to draw on the pricing proposals put forward by ETNO.

3) We are of the view that the approach of Regulatory Neutrality should be adopted in India; the simple guiding principle should be "Same service, Same rule".

4) In the Indian context the following guiding principles need to be adopted:

   a. We support a free and open Internet and believe that consumers should decide what to do online. Our endeavor is to enable consumers to benefit from the freedom of the internet.
   b. We offer choice and do not block or provide any preferential access to any website or app.
   c. Net Equality
   d. Same service, same rules
   e. Please refer to Paper titled - The FCC's "Net Neutrality" rules are technically unworkable by Martin Geddes (enclosed as Annexure 3).
   f.

5) We believe that bilateral arrangements agreed on mutual terms will work the best in the Indian scenario.

Q9: What are your views on net-neutrality in the Indian context? How should the various principles discussed in para 5.47 be dealt with? Please comment with justifications.

COAI Response

1. The issue of net neutrality is a complex issue that is being debated in several countries all over the world and administrations are looking for the right solution to ensure the continued growth of the internet whilst managing the unique challenges of a mobile environment, where capacity is finite due to limited availability of spectrum and huge investments are required to sustain the growth of internet traffic. Operators have to manage their resources and capacity to ensure the best possible customer experience.

2. It may also be kept in mind that India is a market where where 80% of the population still does not have the benefit of broadband coverage and only 7% of the subscribers are availing mobile broadband services. Significant investments are required to meet the broadband targets of the nation. Further, the services need to be accessible as well as affordable and relevant to increase take up of services by the consumers. It is only then that will be able to meet the targets of Digital India program.

3. If Network Neutrality were to be implemented in its strictest sense, i.e. If all traffic is to be treated equally and no innovative commercial arrangements can be entered into by the TSPs to augment their revenues and ensure return on investments, this will necessarily mean an increase in data tariffs for consumers. This will directly impact the growth and take up of services especially for the low end users and the bulk of the Indian population will remain deprived of the benefits of broadband due to affordability concerns.

4. Our ambition is to connect a billion Indians who are not connected today. The immediate priority before the country today is really about net equality and Internet for all.

5. As regards the principles stated in para 5.47:

   - We support and we believe that effective competition amongst TSPs and user choice is already there in the market.
   - We believe that traffic management is a technical and complex exercise and requiring the same to be declared may not be very useful for consumers. However, if at all these are required to be declared, the principles published by Ofcom may be considered.
   - The switching costs and barriers are already very low.
   - The Authority has already issued QOS parameters for wireless data services and we believe that these provide the quality assurance mentioned by the authority and are adequate to protect consumer interest. It is further submitted that there is no basis for the concern that TSPs will degrade traffic to the detriment of any consumer.

6. Further, we believe that if there is enough choice, transparency and low barriers to switching provider, customers will be able to select the option that best suits their needs and Net Neutrality will be safeguarded.

Q10: What forms of discrimination or traffic management practices are reasonable and consistent with a pragmatic approach? What should or can be permitted? Please comment with justifications.

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Q11: Should the TSPs be mandated to publish various traffic management techniques used for different OTT applications? Is this a sufficient condition to ensure transparency and a fair regulatory regime?

COAI Response

1. Traffic management has long been an important tool in meeting the needs of users of internet services and will become more important with the development of new technologies such as LTE, as even voice is delivered over the data networks.

2. Traffic management describes a range of techniques used by network operators, ISPs to ensure the smooth flow of data traffic across the networks between the end users and content /service providers. Network operators and ISPs use traffic management to minimize the incidence and impacts of congestion, ensuring that as many users as possible get the best online experience possible. Examples of current and anticipated network management practices include:

   a. Management of congestion
   b. Blocking spam, malware, denial of service attacks and other security threats to the network or to user devices
   c. Ensuring that time sensitive services such as voice, video, online gaming and enterprise services can be delivered in a way which ensures optimal performance of those applications (without calls dropping, buffering videos and time lags in games)
   d. Network Performance : Network Management practices
   e. Peak Load Management

3.
   a. Mobile network operators face greater constraints in total capacity due to spectrum scarcity and the high costs of infrastructure investment and further because that capacity is then shared amongst users in the access network rather than being dedicated to each individual household. This suggests that any principles governing traffic management should take account of the challenges faced by mobile operators and should be sufficiently flexible to accommodate them. Please refer to Paper tilted Net Neutrality and Technical Challenges of Mobile Broadband Networks by Dr. Jeffrey H. Reed and Dr. Nishith D. Tripathi for more details (enclosed as Annexure – 4).

4. Over the last few years, the amount of data traffic flowing across communications networks has increased dramatically. In addition to increased traffic volumes, network operators have to cope with an increased complexity in the composition of data traffic. While internet traffic was earlier dominated by email and web browsing, we now see a broader range of traffic types including video/music streaming, file transfer protocols,

encrypted packets, online gaming, instant messaging and VOIP etc. Some of these services have a high degree of sensitivity to packet delay, error and loss- undesirable consequence of higher levels of network congestion that follow from increasing traffic volumes.

5. **Traffic management is a tool for consumer benefit not consumer harm**. Traffic management provides a number of clear benefits to end users in terms of improved performance, innovation, consumer protection and efficiency.

6. It is to be noted that traffic management and prioritization has played a large role in the successful introduction of Voice over IP. Again, the use of public mobile internet services for machine-critical-applications is increasingly of interest. The police, fire, and emergency medical services (Public Protections and Disaster Relief i.e. PPDR services) have an increasing need for broadband which have to function in a prioritized way during a natural or a man-made disaster.

7. **Recommendation: Traffic management is a highly technical and complex exercise. The information shared with the consumers must facilitate and empower the consumers to make informed decisions rather than add to their confusion. In view of the above, we submit that mandate to publish traffic management techniques may not be desirable.**

8. However, in the event that such a requirement is considered, TSPs should be given the freedom to communicate their traffic management practices to provide meaningful information and facilitate informed consumer choice. In this regard, we submit that the six principles published by OfCom – viz. appropriate, accessible, understandable, verifiable, comparable and current, may be adopted by the Authority to meet the requirements of transparency. It is essential to provide sufficient information to customers to be clear – too much technical information could be counterproductive.

9. Further, such a requirement may also be applied on other elements of the Internet value chain.

Q12: How should the conducive and balanced environment be created such that TSPs are able to invest in network infrastructure and CAPs are able to innovate and grow? Who should bear the network upgradation costs? Please comment with justifications.

COAI Response

1. The TSPs need a regulatory environment that fosters and incentivizes investments. As submitted above, the revenues from data alone are not sufficient to cover the costs of the TSPs.

2. The TSPs should have the freedom to create new business models and enter into mutual commercial arrangements with OTT players, providing adequate measures for consumer protection. This will support and supplement the huge costs on investments required to increase the bandwidth and capacity to support the growth and take up of OTT services.

3. Such arrangements will be in the interests of all stakeholders – the consumers, the OTT players as well as the service providers.

Q13: Should TSPs be allowed to implement non-price based discrimination of services? If so, under what circumstances are such practices acceptable? What restrictions, if any, need to be placed so that such measures are not abused? What measures should be adopted to ensure transparency to consumers? Please comment with justifications.

COAI Response

1. In mobile networks, an over-congested or degraded network is in no one's interest. One way of ensuring a return on investments could be by recovering the total cost of network upgrades entirely from the consumers, by way of higher data tariffs. Alternatively, one could instead look at the internet as a two sided market which involves the consumer and the content /app provider. The TSP is the platform that brings these two sides of the market together. Payment can come from either side of the market and a two-side payment approach **is a win-win solution – for a content/app provider it will ensure a quality experience for its end user, which will fuel its growth and development, for the consumer, it will mean a more affordable service**.

2. Such arrangements increase social welfare by transferring the cost of internet access from consumers to content providers. Pre-emptive regulation should not come in the way of what can reasonably be defined as an evolution in service provisioning – i.e. we are today capable of entering into complex commercial agreements with the goal to decrease retail prices, and increase the usage of services.

3. In view of the above, we believe that the TSPs should be given the freedom to negotiate commercial arrangements with OTT players. These arrangements should be bilateral in nature, providing adequate measures for consumer protection.

Q14: Is there a justification for allowing differential pricing for data access and OTT communication services? If so, what changes need to be brought about in the present tariff and regulatory framework for telecommunication services in the country? Please comment with justifications.

COAI Response

1. Service Differentiation is a common business practice that is widely practiced across various industries. Take the examples of:
   a. Tatkal rail tickets, first class, sleeper class, unreserved – differentiated products different prices
   b. First class business class and economy class in airlines
   c. National expressway or highway vs a regular road
   d. Travel by bus, taxi or an auto
   e. Priority banking, personal banking
   f. Regular water, mineral water

2. As per a Paper titled, "Network Neutrality orInternet Innovation?" by Mr. Christopher S. Yoo, University of Pennsylvania Law School, "Social welfare would be maximized if the network provider could price discriminate on both sides of the two-sided market (enclosed as Annexure – 2).

3. Such differentiation is also permissible to TSPs. As noted by the Authority, the TTO 1999 provides that the TSP shall not discriminate between subscribers of the same class and such classification shall not be arbitrary. Thus as long as there is a clear differentiation in the classification of subscribers, differential pricing is permitted even under the existing regime. In fact the growth of the market has been fuelled by the various innovative tariff plans that have been designed by the TSPs to meet the wide and varied requirements of their subscribers.

4. In view of the above, we believe that even in the matter of OTT, TSPs should be allowed differential pricing for data access and OTT communication services as long as the TSP shall not discriminate between subscribers of the same class and such classification shall not be arbitrary.

5. As per the provisions of the TTO, 1999 and its amendments, the tariff for data (Internet) is under forbearance. However, all TSPs have to comply with regulatory principles of inter-alia, non-discrimination and non-predation.

Q15: Should OTT communication service players be treated as Bulk User of Telecom Services (BuTS)? How should the framework be structured to prevent any discrimination and protect stakeholder interest? Please comment with justification.

&

Q16: What framework should be adopted to encourage India specific OTT apps? Please comment with justifications.

<u>COAI Response</u>

1. We submit that OTT cannot be called Bulk User of Telecom Services (BuTS).

2. It may therefore not be appropriate to treat OTT communication services players Bulk User of Telecom Services or devise a regulatory framework based on such a premise.

Q17: If the OTT communication service players are to be licensed, should they be categorized as ASP or CSP? If so, what should be the framework? Please comment with justifications.

COAI Response

1. As submitted above, there is a need to ensure Regulatory Neutrality so that there is a level playing field in the eco-system.

2. The Authority should apply the principle of, "Same services, same rules". Only under such an environment, the TSPs will get a fair chance to compete with OTTs on similar pricing and terms.

Q18: Is there a need to regulate subscription charges for OTT communication services? Please comment with justifications.

COAI Response

1. There is no need to regulate subscription charges for OTT communication services and the tariffs should continue to be under forbearance

2. The TSPs should be given the freedom to negotiate commercial arrangements with OTT players. These arrangements could be bilateral in nature, providing adequate measures for consumer protection.

Q19: What steps should be taken by the Government for regulation of non-communication OTT players? Please comment with justifications.

COAI Response

1. We believe that the Authority should look at which obligations should be extended to all internet services – these could be obligations around transparency, privacy, security and

consumer protection, to encourage growth, create a resilient and safe internet and build consumer confidence and trust.

2. Then, the specific requirements needed for communications services should be considered, driven by clear policy requirements. The same rules should apply to the same services.

Q20: Are there any other issues that have a bearing on the subject discussed?

COAI Response

2. Please find enclosed:

    a. Annexure 2 - Paper titled - Network Neutrality orInternet Innovation? by Mr. Christopher S. Yoo , University of Pennsylvania Law School.
    b. Annexure 3 - Paper titled - The FCC's "Net Neutrality" rules are technically unworkable by Martin Geddes.
    c. Annexure 4 - Paper tilted Net Neutrality and Technical Challenges of Mobile Broadband Networks by Dr. Jeffrey H. Reed and Dr. Nishith D. Tripathi.

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Granting network providers pricing flexibility should reduce the costs borne by consumers.

Network Neutrality or Internet Innovation?

By Christopher S. Yoo
University of Pennsylvania Law School

Network neutrality has received sustained attention from both policymakers and academic commentators for the past several years, and it shows no signs of retreating from the forefront of the policy debate. President Obama effectively ensured that network neutrality will remain at the top of the policy agenda by including provisions in the 2009 stimulus package that require the Federal Communications Commission to formulate a national broadband plan. The stimulus package also requires that grants made by the National Telecommunications and Information Administration comply with four network neutrality principles first articulated by the FCC in 2005. On October 22, 2009, the FCC initiated proceedings to codify and expand the 2005 principles. President Obama reaffirmed his support for network neutrality in a YouTube interview conducted shortly after his 2010 State of the Union address.

Pinning down a precise definition of network neutrality is difficult. Roughly speaking, it requires network providers to route traffic without regard to the source or content of the packets of data that move across the Internet, the application with which those packets are associated, or the sender's willingness to pay. In the words of leading network neutrality proponent Lawrence Lessig, "Net neutrality means simply that all like Internet content must be treated alike and move at the same speed over the network."

It would be surprising if any two similar packets would be treated exactly alike when traveling through a network consisting of more than 30,000 autonomous systems that determine their terms of interconnection through arms-length negotiations. Indeed, many commentators have noted that such equal treatment did not occur over much of the Internet's past, when it was far less complex. Now, systematic changes in the architecture of the Internet make identical treatment even less likely, yet the changes are largely the result of network providers' attempts to reduce cost, manage congestion, and maintain quality of service. These changes may not represent network providers' efforts to promote their self interests at the expense of the public, as some network neutrality proponents have suggested, but instead they have the potential to yield substantial benefits both to individual consumers and to society as a whole.

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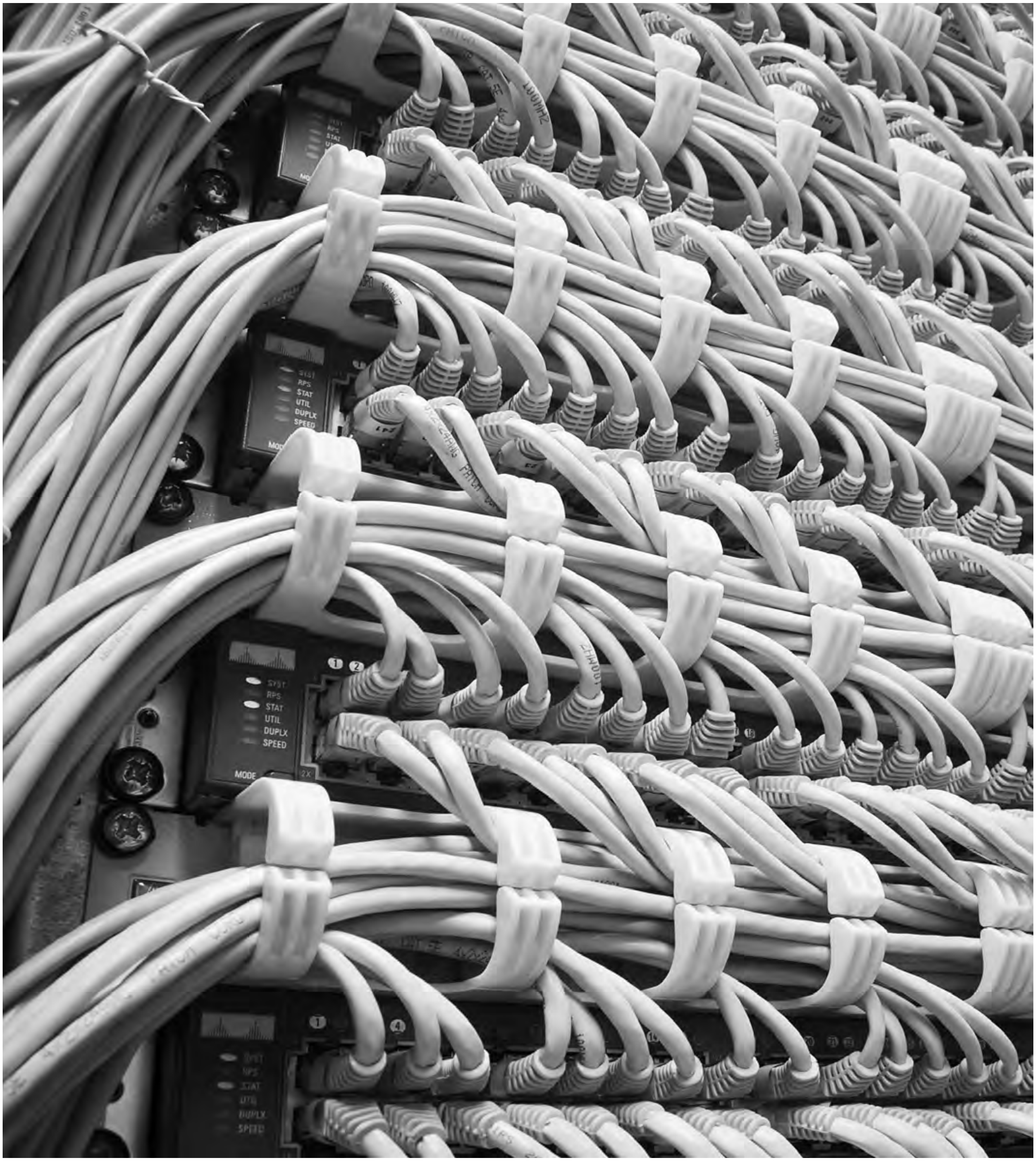
This article is adapted from "Innovations in the Internet's Architecture that Challenge the Status Quo," appearing in the Winter 2010 issue of the *Journal on Telecommunications and High Technology Law*.

THE EARLY INTERNET

When the Internet first emerged, its topology and the business relationships comprising it were relatively simple. The Internet evolved out of the National Science Foundation's NSFNET backbone, which was created in 1986 (and decommissioned in 1997) to provide universities all over the country with access to federally funded supercomputing centers located at five major universities. The primary architects of NSFNET decided to give it a tripartite structure. At the top was the NSFNET backbone, which at its peak connected 16 research facilities across the country. At the bottom were the campus networks run by individual universities. In the middle were regional networks (typically operated by university consortia or state-university partnerships) that linked the campus networks to the major computing centers.

Every data packet had to travel through a parallel path traversing each level of the hierarchy. For example, traffic originating on one campus network would have to connect to the regional network with which it was associated, which hand-



MAXIM FILIPCHUK/ISTOCKPOHOTO

ed off the traffic to the NSFNET backbone, which in turn handed it off to the regional network that served the destination campus network. The result was to create a series of parallel hierarchies through which all traffic had to traverse.

The network retained this same basic architecture when it was privatized during the mid-1990s. The NSFNET backbone at the top of the hierarchy was replaced by a series of private backbone providers that interconnected with one another at four public network access points established by the National Science Foundation. The campus networks at the bottom of the hierarchy were replaced by last-mile providers that transported traffic from local distribution facilities located in individual cities (which in the case of digital subscriber lines are usually called "central offices" and in the case of cable modem systems are usually called "headend") to end users' residences and places of business. The regional networks evolved into regional Internet service providers (ISPs) that transported traffic between the four network access points served by backbone providers and the central offices and headends maintained by last-mile providers.

The privatization of the Internet did not change the hierarchical nature of the basic architecture. Each regional ISP still connected to a single backbone provider, and each last-mile provider still connected to a single regional ISP. Indeed, the early versions of the routing protocol employed by the backbones (known as "border gateway protocol") would not support more complex topologies.

This architecture conferred a number of advantages. It constituted a "spanning tree" that connected all of the nodes with the minimum number of links. Furthermore, the fact that the path between any two nodes was unique greatly simplified determining the path along which traffic should be routed. That said, tree architectures are also subject to a number of drawbacks. The uniqueness of the path connecting any two nodes means that the failure of any link or node in the network will inevitably disconnect part of the network. Even when all network elements are operating properly, if the rate at which traffic arrives exceeds any particular element's capacity to route the traffic, that network element will become congested and the quality of service provided will deteriorate. In addition, the hierarchical structure made each network participant completely dependent on the players operating at the level above them, which in turn provided backbones with a potential source of market power.

Peering and Transit The early Internet was also characterized by relatively simple business relationships. End users typically purchased Internet access through some form of "all-you-can-eat" pricing, which allowed them to consume as much bandwidth as they would like for a single flat rate. Relationships between network providers typically fell into two categories. Tier-1 ISPs entered into "peering" relationships with one another, in which they exchanged traffic on a settlement-free basis and no money changed hands. The primary justification for foregoing payment is transaction costs. Although the backbones could meter and bill each other for the traffic they exchanged, they could avoid the cost of doing so without suffering any economic harm so long as the traffic they exchanged was roughly symmetrical; such arrangements would not be economical if the traffic being exchanged were severely imbalanced. Thus tier-1 ISPs will not peer with other networks that are unable to maintain a minimum level of traffic volume. In addition, peering partners typically require that inbound and outbound traffic not exceed a certain ratio. Networks that cannot meet these requirements must enter into "transit" arrangements in which they pay the backbone to provide connectivity to the rest of the Internet.

Most early analyses of these arrangements focused on their financial terms. What is often overlooked is that interconnection agreements covered two distinct functions: the sending and receiving of traffic, and the announcing to the rest of the Internet where IP addresses served by various providers are located. To understand this latter function, consider the perspective of a small network, *A*, that serves a small number of its own customers and purchases access to the rest of the Internet through another ISP. The transit agreement between *A* and the ISP would not only require the ISP to receive traffic sent by *A* and to deliver traffic bound to *A*, but also require the ISP to announce to the rest of the Internet how to reach the IP prefixes associated with *A*'s customers. In addition, *A* can maintain a very simple routing table — it need only keep track of the prefixes of the customers that it serves; for all IP addresses outside of *A*, it can enter a "default route" into its routing table that directs all other traffic to the other ISP.

The existence of default routes creates a potential problem. If none of the routing tables involved in a particular routing session contained the location of the destination, by default the networks would simply hand the packets back and forth continuously and the packets would never reach their final destination. The only way to avoid this problem is for one or more network providers to maintain routing tables that map the entire Internet without employing any default routes. Thus, tier-1 ISPs are defined not only by their engaging in settlement-free peering with one another, but also by their maintaining routing tables that contain no defaults. Peering contracts also include a number of other requirements to guard against free riding and to ensure the proper functioning of the network.

THE INTERNET'S EVOLUTION

Over the past decade, ISPs have begun to enter into more complex interconnection arrangements that deviate from the strict tripartite hierarchy that characterized the early Internet. In addition, content providers have begun to experiment with a variety of ways to locate their content closer to end users. Both types of changes have significant implications that have largely been overlooked in the policy debate.

Private Peering, Multihoming, and Secondary Peering One of the first problems to emerge in the early Internet was congestion at the four network access points, which often caused throughput times and network reliability to degrade. Some estimate that this congestion caused packet loss at rates as high as 40 percent. As the network access points became increasingly congested, backbones began to find it advantageous to exchange traffic at private interconnection points, a practice known as "private peering."

In addition, regional ISPs have begun to connect to more than one backbone, a practice known as "multihoming," in part to protect against service outages and to limit their vulnerability to any exertion of market power by a backbone. Regional ISPs that did not have sufficient volume to peer with the tier-1 backbones also began to find that they did have sufficient volume to peer with other regional ISPs, a practice known as "secondary peering." Enabling regional ISPs to exchange traffic on a settlement-free basis reduced the costs borne by end users. In addition, secondary peering would often shorten the number of hops needed for particular packets to reach their final destination and make them subject to bilateral (as opposed to multiparty) negotiations, both of which should increase networks' control over quality of service. Secondary peering and multihoming also made the network more robust by creating multiple paths through which network nodes could interconnect. In fact, as much as 70 percent of the nodes in the Internet can now communicate with one another without passing through the public backbone. This had the additional benefit of weakening the market position of the top-tier backbones, since any breakdown in the business relationship would not necessarily disconnect the ISP from the network and the ability to route along different paths places a natural limit on the backbones' ability to engage in supracompetitive pricing.

The emergence of interconnection relationships that deviate from the strict hierarchy that characterized the early Internet represents a substantial divergence from network neutrality. For example, assume that an end user is downloading content from both CNN.com and MSNBC.com. Assume further that the end user's regional ISP has a secondary peering relationship with the regional ISP serving CNN.com, but does not have a secondary peering relationship with the regional ISP serving MSNBC.com. The absence of a secondary peering relationship means that traffic from MSNBC.com will have to pay transit charges, while traffic from CNN.com will not. The result is that traffic that is functionally identical will end up paying different amounts. The differences in topology may also allow the traffic from CNN.com to maintain greater control over the quality of service.

The presence of multiple routes between these two points also complicates routing decisions. The presence of multiple paths connecting two points naturally means that someone must decide along which path to route the traffic. Although most networks choose routes that minimize the number of hops, networks may sometimes find it beneficial to route traffic in order to satisfy other requirements of their interconnection relationships. For example, a network may seek to enhance efficiency by balancing the loads between the two links. Multihomed entities can also monitor the quality of service provided by each connection and route the most delay-sensitive traffic along the link with the lowest latency.

In addition, transit contracts call for customers to pay a flat fee up to a predetermined peak volume (known as the committed rate) and pay additional charges for any volume that exceeds that level. For the same reason that consumers with two mobile telephones have the incentive to use up all of the prepaid minutes on both lines before incurring any additional per-minute charges, multihomed entities have the incentive to utilize all of their committed rate before paying additional fees. This lowers overall transit cost, but requires diverting some traffic along a path that is longer than the one stored in the routing tables. For similar reasons, a network may intentionally route traffic over a more costly path if doing so will help it maintain its traffic within the ratios mandated by its peering contract. Again, the effect is to introduce significant variance in the speed with which similarly situated packets will arrive at their destination and the cost that similarly situated packets will have to bear. This variance results not from anticompetitive motives, but rather from networks' attempts to minimize costs and ensure quality of service in the face of a network topology that is increasingly heterogeneous.

Server Farms and CDNS Large content providers have begun to employ other means to reduce cost and manage latency. One solution is to forgo maintaining a single large server and instead to deploy multiple points of presence in "carrier hotels" across the country. Doing so allows these content providers to avoid paying transit charges to reach the public backbone and instead transmit their traffic through secondary peering arrangements with tier-2 ISPs. Greater reliance on private networks also gives the content providers greater control over network security and performance. A recent study indicates that Google, Yahoo!, and Microsoft have been able to use server farms to bypass the backbone altogether for roughly a third of their traffic, and to keep their number of hops for traffic that had to pass through the backbone to no more than one or two.

On other occasions, content providers are distributing their data through "content delivery networks" (CDNs) such as Akamai and Limelight. CDNs in effect substitute storage for long-distance networking capacity by maintaining a network of local caches across the Internet. When an end user sends a request for a webpage hosted by a CDN, that query is redirected to the cache. CDNs are thus able to use storage to serve multiple queries for the same content without using significant network resources. The geographic dispersion of the caches usually dictates that the file will be served by a location closer than would be possible if all of the content were stored in a central server, which minimizes cost and latency. The distributed nature of the caches also provides protection against denial-of-service attacks and allows the CDN to redirect queries to other caches when particular caches are overly congested.

CDNs represent an innovative way to deal with the increasing complexity of the Internet. The problem is that they are nonneutral. CDNs work best for static content; they are less well suited to interactive content that changes dynamically. More to the point, CDNs are commercial services; thus greater

Secondary peering and multihoming have the benefit of weakening the market position of the top-tier backbones.

reliability and quality of service are available only to those who are willing to pay for them.

To the extent that CDNs use the public backbone to deliver the content to their caches, they are best regarded as an overlay to the existing network. Increasingly, however, CDNs and server farms are bypassing the public backbone altogether and connecting to their caches through private networks, in the process transforming CDNs into a fundamentally different architecture.

All of these developments represent innovative adjustments to the realities of the Internet. The differences in topology mean that traffic that is otherwise similar may travel through the network at different speeds, with different costs, and with different levels of quality of service.

THE EVOLUTION OF BUSINESS RELATIONSHIPS

The evolution of the Internet has not been restricted to topology. Network participants have also been experimenting with an increasingly broad range of business arrangements. Some of these innovations have been driven by the increasing significance of peer-to-peer technologies. Other important developments are partial transit and paid peering.

Peer-To-Peer One of the primary forces causing business relationships to change is the growing importance of applications using peer-to-peer technologies. The traditional Internet employed what is known as a client-server architecture, in which files are stored in large computers at centralized locations (servers) and end users (clients) request files from those computers. The relationship is generally regarded as hierarchical, and the amount of data uploaded by clients is very small relative to the amount of data downloaded by servers. In the classic example of the World Wide Web, client traffic consists solely of uniform resource locators (URLs), the short bits of code identifying a particular website address. Server traffic, which consists of the data comprising the requested website, is much larger. For this reason, the technologies that took the early lead in broadband deployment (cable modem service and DSL) adapted an asymmetric architecture, allocating a larger proportion of the available bandwidth to downloading than to uploading. Newer technologies, such as fiber and wireless broadband, follow the same pattern.

Peer-to-peer technologies follow a very different approach. Edge computers in a peer-to-peer architecture are not divided into those that host files and those that request files. Instead, computers simultaneously perform both functions. Because this relationship is regarded as less hierarchical than client-server relationships, the computers in this architecture are known as peers and communications between them are known as peer-to-peer. Peer-to-peer is thus not synonymous with file sharing or user-generated content, as is often mistakenly assumed. On the contrary, many peer-to-peer applications (such as Vuze) support commercial broadcast services, and many platforms for user-generated content (such as YouTube) employ centralized servers. The real significance of the term "peer-to-peer" lies in the nature of the network architecture.

It is not yet clear what proportion of network traffic will follow each architecture. For example, peer-to-peer traffic had consistently outstripped client-server traffic for several years leading up to 2007. In 2007, however, client-server traffic staged a comeback, thanks primarily to the expansion of streaming video services like YouTube, and exceeded peer-to-peer traffic 45 percent to 37 percent. Many industry observers now predict that although peer-to-peer will remain important, it will decline as a percentage of total Internet traffic over the next several years. Even so, it is clear that peer-to-peer traffic is likely to remain a more important component of network traffic than during the Internet's early years.

The growing importance of peer-to-peer technologies is causing significant congestion in certain areas of the network and is putting pressure on the traditional approach to pricing network services. The emergence of end users as important sources of data is putting severe pressure on the limited bandwidth allocated to upload traffic. In addition, unlike in a client-server architecture where end users usually only generate traffic when a person is seated at the keyboard, edge computers in a peer-to-peer architecture can generate traffic for as long as the computer is left running. The result is that the lion's share of upload traffic is generated by a small number of superheavy peer-to-peer users. As few as 5 percent of end users may be responsible for generating more than 50 percent of all Internet traffic.

The most recent generation of peer-to-peer technologies can exacerbate congestion still further. In the first generation of peer-to-peer technologies, each end user stored the entirety of the files that the user hosted. As a result, anyone requesting those files was limited by the total bandwidth and the level of congestion associated with the network connection attached to that end user's computer. Technologies such as BitTorrent follow a different approach. Instead of storing entire files in one location, BitTorrent divides each file into

The differences in topology mean that traffic that is otherwise similar may travel through the network at different speeds, with different costs.

pieces and distributes them at multiple locations around the Internet. When a BitTorrent user requests a file, the software then retrieves the various pieces from multiple computers at the same time, which reduces the amount of bandwidth required from any one peer and improves download performance. BitTorrent also dynamically reallocates requests for pieces away from the slowest connections and toward the fastest connections, thereby placing the heaviest burden on those peers with the fast connections.

The congestion caused by peer-to-peer technologies weighs heaviest on last-mile technologies that share bandwidth locally, such as cable modem and wireless broadband systems. For example, cable modem technology requires that subscribers share bandwidth with the other households operating through the same neighborhood node. As a result, cable modem customers are significantly more vulnerable to the downloading habits of their immediate neighbors than are telephone-based broadband systems, which offer dedicated local connections. Service can slow to a crawl if as few as 15 of the 500 or so users sharing the same node are using peer-to-peer applications to download files.

The classic economic solution to congestion is to set the price of incremental network usage equal to the congestion costs imposed on the network by that usage. However, determining the congestion cost imposed by any particular user at any particular time can be quite complex. Subscribers that use large amounts of bandwidth can contribute very little to network congestion if they confine their usage to hours when network usage is low. Conversely, subscribers that use only small amounts of bandwidth may nonetheless impose significant congestion costs on the network if they generate traffic at peak times. The contribution of any particular usage cannot be determined simply by counting the number of bits being transmitted. The overall impact of any particular increase in network usage can only be determined in light of other subscribers' Internet usage. Thus it may make sense to charge different amounts to users who are using the Internet to access the same content or application if a sufficient number of other users sharing the same bandwidth are using the network at the same time.

The growth of peer-to-peer technologies has also heightened the pressure on the models that network providers have used to price their services. As noted earlier, the traditional approach charges content and application providers prices that increase with the peak bandwidth consumed, while end users are charged on an unmetered basis. The fact that every download had to pass through one link that charged on a volume-sensitive basis allowed this pricing approach to serve as a reasonable approximation of efficient congestion pricing. For example, 100 downloads of a 700 megabyte movie would generate 70 gigabytes of traffic from the server, which in turn would be reflected in the price paid by the content provider to its ISP.

The situation is quite different under peer-to-peer architecture. In that case, the movie could be downloaded once from the server, and the remaining 99 downloads could be served by other end users running the same peer-to-peer software. Because end users are provided with service on an all-you-can-eat basis, the additional 99 downloads served by the peer-to-peer network do not generate any additional revenue. The only revenue received by the network is for the initial 700 megabyte download. Thus, in a peer-to-peer architecture, the amounts that content providers pay under the traditional pricing regime no longer serve as a workable approximation of the total traffic they impose on the network. Moreover, the failure to charge network participants prices that reflect their incremental contribution to congestion causes excessive consumption of network resources that ultimately harms consumers.

It thus comes as no surprise that the network providers that are most subject to local congestion are experimenting with other means for managing the congestion caused by peer-to-peer applications. For example, Time Warner has recently experimented with bandwidth caps and other forms of metered pricing. Although many network neutrality proponents have no objection to metered pricing, recent attempts to impose metered pricing and bandwidth caps have met such a hostile reaction from the network neutrality community that the network providers had to back down. That said, metered pricing is far from a panacea. As I have discussed in greater detail elsewhere, true congestion-based pricing would vary from moment to moment based on the volume of traffic introduced into the network by other users. Such a pricing regime would challenge consumers' ability to process the relevant information, and the distributed nature of the Internet means that no one entity has the information needed to formulate such policies. As a result, other network providers have turned to proxies that are strongly associated with high-volume activity, which most importantly includes a ban on operating a server as required by peer-to-peer technologies. Although this would constitute a violation of network neutrality by discriminating against a particular type of application, even network neutrality proponents acknowledge that such a restriction represents a good proxy for bandwidth-intensive activity.

Partial Transit and Paid Peering Network providers have also begun to enter into business relationships that go beyond peering and transit relationships that dominated the early Internet. Some are driven by the emergence of secondary peering relationships discussed above. Before such relationships existed, a tier-2 or tier-3 ISP would have to buy transit from a tier-1 ISP that had obtained access to all of the IP addresses that it did not serve. In other words, a tier-2 or tier-3 ISP's transit relationships would cover the entire Internet (except for its own customers).

The advent of secondary peering reduces the scope of transit services that the ISP needs to purchase. The ISP no longer needs to buy transit to the entire Internet; the secondary peering relationships already provide the ISP with the ability to reach those customers served by its secondary peering partners. As a result, these ISPs have begun to purchase partial transit that covers only those portions of the Internet not already covered by their secondary peering relationships.

In addition, an ISP with inbound traffic that far exceeds its outbound traffic may run the risk of having traffic ratios that put it in violation of its peering contract. Under these circumstances, it may attempt to cover its deficit in outbound traffic by selling a partial transit contract that covers only outbound traffic, but not inbound traffic. Alternatively, it may reduce its inbound traffic by buying partial transit for inbound traffic.

Another interesting development is the emergence of paid peering, which involves all of the same aspects as conventional peering relationships. Peers announce to the rest of the Internet the addresses that their peering partners control, maintain a sufficient number of interconnection points across the country, and maintain the requisite total volume and traffic ratios. The key difference is that one peering partner pays the other partner for its services.

Paid peering is driven by both supply-side and demand-side considerations. Starting first with the supply side, settlement-free peering arrangements between tier-1 ISPs with similar traffic volumes make sense only if both networks have similar costs. Over time, backbones have begun to serve two different types of last-mile networks: those such as Cogent and Abovenet that primarily serve content and application providers (which are sometimes called "content networks"), and those such as Comcast and Verizon that serve end users (which are sometimes called "eyeball networks"). The costs of the first type of network are quite low, typically only requiring a single high-speed line to a small number of business locations. The costs of the second type of network are considerably higher, requiring the wiring and upgrading of equipment in entire neighborhoods. The presence of such asymmetric costs provides a substantial impetus for cash to flow from networks serving content and application providers to networks providing connections to end users.

These supply-side considerations are reinforced by demand-side considerations associated with the economics of two-sided markets, which illustrates the potential benefits of allowing network providers to charge differential prices to both end users and content and application providers. Conventional economics has long recognized the existence of "network economic effects," which cause a network to increase in value as the number of users connected to it increases. To use a classic example, the value of a telephone network to a particular consumer depends in part on the number of other subscribers connected to the network; the more people you can reach through the network, the more valuable it becomes.

The benefits created by the network economic effect for telephone networks arise with respect to a single class of customers. When a market is two-sided, instead of bringing together a single class of similarly situated users, networks bring together two completely different classes of users. In those cases, the value is determined not by the number of users of the same class, but rather by the number of users of the other class. A classic example is broadcast television, which brings together two groups: viewers and advertisers. Advertisers gain no benefit (and if anything suffer a detriment) from belonging to a network with a large number of other advertisers. The value of the network for advertisers is instead determined solely by the number of viewers, i.e., the size of the other class of users.

The literature suggests that social welfare would be maximized if the network provider were permitted to price discriminate on both sides of the two-sided market. It also suggests that the prices paid on each side of the market can differ widely, and that in many cases it is economically beneficial for one side to subsidize the other side. The fact that the Internet has become increasingly dominated by advertising revenue paid to content and application providers suggests that it may be socially beneficial for content and application providers to subsidize the prices paid by end users. An advertiser's willingness to pay for an ad on a particular website depends on the number of end users viewing that website. Under these circumstances, the optimal solution may be for the website owner to subsidize the total number of end users by making payments to the network provider to help defray their costs of connection. The costs of subsidizing more users would be more than offset by the additional revenue generated by the fact that advertisers can now reach more potential customers. In the case of broadband, this would be both economically efficient and would be a boon to consumers both in terms of providing service in more geographic areas and in reducing the prices that consumers pay.

These dynamics are again well illustrated by broadcast television. In many ways, broadcast television and the Internet are analogous. The studios that create television programs play a similar role to content and application providers. Television networks aggregate programs and deliver them nationally in much the same manner as content networks and backbone providers. Local broadcast stations provide last-mile connectivity that is quite similar to the role played by eyeball networks. In addition, the revenue structure is quite comparable, in that television networks receive advertising revenue

Social welfare would be maximized if the network provider could price discriminate on both sides of the two-sided market.

in much the same manner as content and application providers. Furthermore, the cost structure is somewhat similar in that connecting individual homes is much more costly than distributing programming nationally.

For decades, the standard business arrangement has been for television networks to subsidize the operations of local broadcast stations by paying them to be members of their television networks. The industry's revenue and cost structure make such arrangements quite logical. The cost of paying these broadcast stations to affiliate with a network is more than offset by the increase in advertising revenue made possible by the fact that the network is now able to reach a larger audience. Broadcast television thus represents a prime example of when firms operating on one side of the market find it economically beneficial to subsidize end users on the other side of the market.

Furthermore, the magnitude of the affiliation fees that the networks pay to broadcast stations is anything but uniform. The precise amount varies with the relative strength of the network and the relative strength of the broadcast station. Stronger broadcast stations receive more, while weaker ones receive less. Equally interesting is the fact that in recent years, the cash flow has begun to vary in its direction as well as magnitude, with weaker stations having to pay rather than being paid to be part of the television network. The dynamic nature of this pricing regime benefits consumers by providing incentives for networks to invest in better quality programming and by providing an incentive for stations to provide better carriage.

The two-sided market analysis reveals the potential drawbacks of preventing network providers from charging differential prices. As a general matter, pricing flexibility makes it easier for network providers to recover the costs of building additional bandwidth. Granting network providers pricing flexibility with respect to content and application providers should reduce the percentage of the network costs borne by consumers. Conversely, preventing network providers from exercising pricing flexibility with respect to content and application providers would simply increase the proportion of the network costs that providers must recover directly from end users. This simultaneously raises the prices paid by consumers and decreases the likelihood that the capital improvements will ever be built. Charging content and application providers differential prices thus has the potential to increase social welfare and can reduce, not increase, the burden borne by consumers.

CONCLUSION

It is all too easy to forget that the Internet is not a monolith with a brooding omnipresence overseeing the entire system. Instead, it is a collection of autonomous systems that determine the terms of interconnection between them through a series of arms-length negotiations. Given the Internet's essence as a network of networks, it should come as no surprise that no two packets will pay the same amount for the same service.

The developments that I have outlined in this article have made such differences even more likely. The network no longer adheres to the rigid and uniform hierarchy that characterized the early Internet and its predecessor, NSFNET. Data packets can now travel along radically different paths based on the topology of the portion of the network through which they travel. This is the inevitable result of reducing costs and experimenting with new structures. At the same time that network providers are experimenting with new topologies, they are also experimenting with new business relationships. Gone are the days when networks interconnected through peering and transit and imposed all-you-can-eat pricing on all end users. That fairly simple and uniform set of contractual arrangements has been replaced by a much more complex set of business relationships that reflect creative solutions to an increasingly complex set of economic problems. Again, these differences mean that the service that any particular packet receives and the amount that it pays will vary with the business relationships between the networks through which it travels. Although many observers reflexively view such deviations from the status quo with suspicion, in many (if not most) cases, they represent nothing more than the natural evolution of a network trying to respond to an ever-growing diversity of customer demands. Imposing regulation that would thwart such developments threatens to increase costs and discourage investment in ways that ultimately work to the detriment of the consumers that such regulation is ostensibly designed to protect. R

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The FCC's "net neutrality" rules are technically unworkable

I have been watching with dismay the commentary and debate following the US Federal Communications Commission's issuing of its rules on the contentious issue of "net neutrality". Regrettably, they have proceeded to issue rules without having their science in order first. As a result they have set themselves up to fail. My fear is that other countries may attempt to copy their approach, at a high cost to the global public.

Let's take a look at the three core rules, and why they are unsuitable.

No blocking

At first sight this seems like an obviously desirable thing. However, it wrongly assumes a known universe of end points to connect to. For example, a decade from now there will be billions of new connected smart devices. Will an ISP have to route to all of them? How will the FCC differentiate between "blocking" and "places our ISP service doesn't happen to route to"?

This becomes particularly problematic in a future world of virtualised services, which is the logical end point of technologies like SDN and RINA. Every device will potentially experience its own "virtual Internet" (rather like a VPN or VLAN). It may be undesirable to make all end points reachable by everyone, for a variety of cost, performance and security reasons.

An assumption being made with "no blocking" is that all end points should automatically be associated with each other. This is an artefact of the Internet's primitive prototype design and protocols. In more advanced architectures (such as RINA, and prospectively 5G) association management is an explicit primitive. You can't route to another point without associating first (and there is a security process to get through, which might say "no").

Furthermore, the idea of "public" IP addresses (being like phone numbers) is an anachronism. The Internet is not actually a true "inter-network", as it lacks any gateways that hide the implementation of one network from the next. As a result it is more like a global LAN using a global address space, with the resulting security and performance nightmares. "No blocking" is based on a backwards-looking view of technology to the 1970s.

For that matter, why should any ISP be forced to offer access to Netflix? Why can't an ISP offer "100% guaranteed Netflix-free!" service at a lower price to user who don't want to carry the cost of their neighbours' online video habit? Or an ISP service that doesn't connect you to web sites with the letter "z" in the domain name? A basic freedom of (non-)association is being lost here.

The real issue is the conjoining of the ISP service and local broadband access, with a market bottleneck for the latter. In dial-up you had a choice of ISPs, so this ISP-level issue didn't matter. To this foreigner, "no blocking" is a competition issue for the FTC and antitrust law, not the FCC.

No throttling

Again, this seems like an obvious "good thing". I bought a 10Mbit/sec broadband plan, and you're only delivering me 5, what gives?

Yet this is a naive understanding of broadband. "No throttling" assumes an intentional semantics to network operation that doesn't exist. In other words, it assumes that the service is supposed to exhibit certain performance behaviours. Yet broadband is a stochastic system whose properties are entirely emergent (and potentially non-deterministic under load). An ISP can, in principle, legitimately exhibit any possible behaviour.

How will a regulator distinguish between "throttling" and mere "unfortunate statistical coincidences leading to bad performance"? How will they define what performance is supposed to be delivered, and to whom? Why should someone who merely demands more resources be given them? Where's the fairness in that!

What's the metric used to determine if "throttling" has taken place? If it's "speed", then me and my evil packet scheduling friends and deliver an ISP service with good speed but terrible quality. Indeed, "speed" encourages ISPs to optimise for long file downloads, not interactivity.

So what are the proposed metrics for performance and methods for measuring traffic management? What's the reference performance level for the service? Without these, "no throttling" is meaningless and unenforceable.

The real issue is whether the service performance is good enough to deliver the QoE outcome(s) that the user seeks. How can the user know if the service will be fit for purpose?

No paid prioritisation

This rule raises the bogeyman of "fast lanes", which conflates two distinct issues. The first is of having multiple explicit classes of service (a "polyservice" network), and the second being who pays (retail or wholesale side).

Inhibiting the very necessary exploitation of traffic scheduling is technical madness. It ensures the non-scalability of the Internet to satisfy growing quality and quantity needs. Thankfully, it's only a few neutrality extremists who think all packets were created equal and FIFO queues are divine creations. Yet this rule appears to leave us with "no prioritisation" as a proposed future. Are they serious?

Determining in advance that the wholesale side cannot pay for assurance simply prevents a rational market pricing for quality. This also dumps a ton of complexity onto end users. Now grandma potentially needs to purchase and provision the right quality assurance for each service or application she uses. I hope she gets the codec right in that drop-down box...

We already have "paid priority", and nobody died. All CDNs offer *de facto* priority by placing content closer to the user, so it can out-compete the control loops of content further away.
Paid peering is perfectly normal. Indeed, nobody bats an eyelid when Amazon sends you physical goods via a parcel service. So why the panic over digital goods?

The real issue is the separation of the immutable delivery cost issues from everything else, and pricing the service appropriately to reflect those costs.

Time for some hard science to inform policy

Both sides of the debate in the US has been fuelled by campaign groups who are often funded by rich corporations and donors. It's a battle between Big Content and Big Telco over who carries the cost of delivering bulky and quality-demanding services. There's little of principle at stake. It's about power and privilege.

A lot of (legal) academics have written on the subject, with some offering reasoning that unsurprisingly aligns with the interests of their sponsors. They consistently make the same technical errors:

- Firstly they assume a "virtuous circle" of content and users, ignoring the diseconomies of scale: users are not internalising their cost of using a shared medium, and the cost of association is not zero.

- Secondly, they assume circuit-like behaviours of the Internet, with wholly wrong understandings of "QoS", "congestion" and the network resource trading space.
- Finally, they look backwards to an illusory utopian past of the Internet, rather than planning for the future. (SDN doesn't appear once in the whole FCC order. QED.)

However, technical reality has the last laugh. If you tried to make spectrum policy rules that broke the laws of physics, you'd be ignored by informed people, and the cosmos wouldn't bend. Broadband is similarly constrained by "laws of mathematics". Why don't we try making rules that fit within those, for a change?

The real issue is abuse of power, not abuse of packets. We need a new regulatory approach, grounded in the science of network performance, that directly constrains market power.

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September 4, 2014

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: ***Protecting and Promoting the Open Internet*, GN Docket No. 14-28; *Framework for Broadband Internet Service*, GN Docket No. 10-127**

Dear Ms. Dortch:

The Commission's tentative conclusion to extend a mobile-specific Open Internet framework is grounded in three aspects of the mobile marketplace: mobile broadband faces unique operational constraints; mobile broadband technologies are rapidly evolving; and the "generally greater amount of consumer choice" for mobile broadband services than for fixed.[1] CTIA—The Wireless Association® submits the attached technical paper to help detail the operational constraints in these ever-evolving mobile networks, the complexity of mobile network management, why flexibility is needed, and how prescriptive regulation would undermine mobile broadband operators' ability to provide consumers with the level of service they have come to expect.

The paper, *Net Neutrality and Technical Challenges of Mobile Broadband Networks*, is co-authored by Dr. Jeffrey H. Reed, Willis G. Worcester Professor of Electrical and Computer Engineering at Virginia Tech University and Director of Wireless@Virginia Tech, and Dr. Nishith Tripathi, senior consultant who writes and lectures on mobile technologies. Wireless@Virginia Tech is one of the largest and most comprehensive university wireless research groups in the U.S.

In their paper, Drs. Reed and Tripathi explain in great detail the primary technical factors affecting mobile network management; how mobile broadband providers apply differential treatment to different traffic streams on a real-time, dynamic basis; the stark technological differences between wireless and wireline networks and network management; and the problems that would arise from imposing prescriptive Open Internet regulation on mobile providers. The technical factors they highlight include the following:

- ***Scarcity of radio resources.*** With the explosion in the amount of mobile data traffic, spectrum resources have not kept pace. Mobile broadband operators

[1] Protecting and Promoting the Open Internet, *Notice of Proposed Rulemaking*, GN Docket No. 14-28, FCC 14-61, ¶ 91 (rel. May, 15, 2014); *see also id.* ¶ 62.

are thus constrained, necessitating aggressive and efficient management of limited radio resources.

- ***Radio resource sharing.*** As the number of users being served by the same base station fluctuates, the challenge of providing high-quality service to each of them also grows, requiring providers to make choices regarding how to manage network resources.

- ***Dynamic channel conditions.*** The allocation of radio resources constantly changes due to changing channel conditions and the interference environment, as often as every millisecond.

- ***Varying resource consumption.*** For a given channel condition, different services consume different amounts of resources. Thus, resource allocations change as users shift among different uses – often many times during a given session.

- ***Integration of devices and the network.*** Even when two devices experience identical channel conditions and allocation of radio resources, their design characteristics may dictate widely different throughput, further complicating network management.

- ***Ever-evolving network.*** Mobile broadband providers constantly manage user mobility across various technology generations and revisions across the network, offering differing levels of achievable network performance.

- ***Challenges of network capacity additions***. The intricacies of capacity growth (adding spectrum and wireless infrastructure deployment), along with ever-rising user traffic, make efficient utilization of the existing radio resources extremely critical to the user experience and network efficiency.

Drs. Reed and Tripathi also explain that mobile and fixed networks face vastly different technical challenges. Fixed networks have significantly higher capacity and predictability of resource requirements, whereas mobile networks are far more capacity constrained, with constantly changing user requirements and operating environments. Fixed networks involve channels that are relatively clean with signal regeneration, while mobile channels are impaired with interference, multipath and blockage, varying by location and from one millisecond to the next. As they observe, "The wireline network engineer knows precisely how much bandwidth is available in a single fiber optic strand and (other than losses over distance) will have a near-constant understanding of the performance of the transport layer. In contrast, wireless networks are faced with ever-changing radio environments."

Mobile broadband providers need more flexibility to manage their networks and to ensure that their customers have the service they have come to expect. As the paper explains, that flexibility must include the ability to manage applications to avoid harm to the network and to maintain reliable and efficient service for the aggregate user experience. Similarly, mobile operators should be free from any anti-discrimination or commercial reasonableness requirement that would restrict their ability to innovate, optimize, and differentiate service to deliver a high quality product. In addition, expanded transparency requirements are infeasible in the context of dynamic, ever-changing mobile network operations. As Drs. Reed and Tripathi conclude, more prescriptive mobile rules "would stifle innovation and competition, negatively impact the user-experience and system capacity, and severely limit the ability of mobile wireless networks to meet the unique challenges faced by modern wireless networks."

The paper paints a detailed picture of the difficulties that would be created by the application of an overly broad or overly prescriptive set of rules on mobile broadband. As Reed and Tripathi explain, "subjecting this type of network and network management to broad prophylactic rules with a vague 'exception' standard would provide no clarity to carriers, edge providers, or consumers as to how these networks will be managed. The exception would either simply subsume any rules (e.g., blocking or non-discrimination) or providers would be stripped of their ability to evolve and manage networks for the betterment of the entire subscriber base."

The paper also explains that mobile broadband inextricably intertwines transmission and processing capabilities, and thus remains an "integrated information service." Mobile broadband service involves extensive and complex processing throughout the network to ensure that customers can seamlessly navigate among multiple applications and services, and different network nodes must constantly engage in service-specific processing to support the user's activities. As Drs. Reed and Tripathi show, this tight integration between transmission and processing is essential whether the user is browsing a website, engaged in mobile video conferencing, or undertaking any of the myriad other activities made possible by mobile broadband. This factual finding further confirms the FCC's prior determinations in 2007 and 2010 that mobile broadband Internet access is an integrated information service that must remain subject to a Title I framework. Moreover, the engineering and operational complexities outlined in this report make a Title II common carrier regulatory approach even more problematic.

We look forward to exploring these principles further as the Commission considers how best to promote mobile broadband and the interests of the American consumer.

Sincerely,

/s/ *Scott Bergmann*

Scott Bergmann
Vice President – Regulatory Affairs
CTIA – The Wireless Association®

Net Neutrality and Technical Challenges of Mobile Broadband Networks

Dr. Jeffrey H. Reed and Dr. Nishith D. Tripathi

September 4, 2014

TABLE OF CONTENTS

Figures/Tables

Abstract

As this paper describes in detail, the management of mobile broadband networks is a constantly evolving task. From millisecond to millisecond, handsets with differing capabilities, consumers with different usage patterns, applications that utilize different aspects and capabilities of both the handset and the network, and content consumption, including video, must be integrated with the network and managed adroitly to deliver a world-class broadband experience for the customer. Now imagine that millisecond to millisecond process happening while the consumer is in motion, while the handsets vary in capability (think flip-phone to smartphone), while the available network changes from 3G to 4G and from one available spectrum band to another, while traffic moves into and out of a cell sector, and while spectrum capacity is limited. **This entire process – the integration of all of these different variables – is unique to mobile broadband.** This paper is designed to illustrate and explain this extremely complex, very dynamic process in the context of the FCC's 2014 Notice of Proposed Rulemaking ("NPRM") on net neutrality.

The NPRM seeks comment on several proposed rules and associated mechanisms. In particular, the NPRM seeks comment on three rules that impact the management of mobile broadband networks. First the "transparency rule" requires mobile broadband providers to publically disclose accurate information regarding network management practices, performance, and commercial terms of their broadband Internet access service. Second, the "no-blocking rule," which was vacated by the D.C. Circuit, prohibited mobile broadband providers from blocking consumers from accessing lawful websites, as well as prohibited blocking applications that compete with the provider's voice or video telephony services, subject to "reasonable network management." The Commission is now exploring modifications to these rules. And third, though it tentatively concludes that such a rule should not be imposed on mobile broadband providers, noting its previous findings distinguishing mobile broadband in the context of net neutrality regulation, the Commission also seeks comment on whether it should apply to mobile broadband networks an "anti-discrimination/commercial reasonableness" rule, that would enforce a "commercially reasonable" standard of conduct for broadband provider practices.

This paper demonstrates that any extensions of, or additions to, the FCC's 2010 rules would be unwieldy and over-inclusive when applied to the complex and constantly-evolving management of mobile broadband networks. In fact, with the introduction of LTE, networks are managed and operated in a far more complicated and complex manner than the networks in place in 2010 when the Open Internet Order was adopted. As more of the LTE standard's advanced functionalities are incorporated into wireless networks, the complexity and prioritization in the networks will only grow, as will the benefits to consumers.

This paper addresses, based on the complexity and constantly-evolving management of mobile networks, why several of the proposals could be disruptive to a robust consumer broadband experience, and why some of the Commission's tentative conclusions should be maintained. For example, requiring mobile broadband providers to develop and/or report metrics regarding network management would be extremely difficult from a technical perspective and is unlikely to be useful due to the millisecond-to-millisecond adjustments that are inherent to a mobile broadband network. As described throughout, ever-increasing usage and scarcity of spectrum resources requires active management of the network to address capacity issues in a rapid fashion at the cell (or sector) level based on the demands placed on

the network. Similarly, while the competitive pressures on wireless carriers make imposition of a no-blocking rule unnecessary, broad application of a rule could have a significant negative technical impact on wireless broadband networks.

This paper explains how wireless applications can consume very large quantities of bandwidth, potentially causing problems for the end user or for others nearby. Third-party mobile apps and services can also interfere with and undermine network performance, and wireless network operators must be permitted the flexibility to manage their networks to prevent these negative effects. The NPRM also seeks comment on the feasibility of defining a minimum level of service that broadband networks must provide, proposing several possible standards that could be used. As discussed, such standards cannot be readily quantified for mobile wireless networks given the millisecond-to-millisecond adjustments in the network and would prevent wireless network operators from using techniques critical to ensuring a robust user experience. Also, as handset technology, base station technology, network technology and application technology rapidly change, it is unclear what metrics and standards would apply universally over time to fairly judge capabilities or performance.

The paper also demonstrates that the NPRM's tentative conclusion that an "anti-discrimination/commercial reasonableness" rule need not apply to wireless is the correct one. Differentiation among users and user services is required to provide a satisfactory quality of service to consumers. This is due to the dynamic nature of the radio environment and the need to operate good scheduling algorithm designs in a wireless network that maximize network performance while providing a good user-perceived experience. It is also due to product differentiation within a competitive marketplace in terms of what devices, features, and services might be offered as part of a carrier's service plan.

Finally, the paper explains that without today's real-time sophisticated scheduling algorithms that support network management that enables the service operator to cost-effectively provide services to many users simultaneously, overall user experience and network throughput will suffer. Treating all users alike at all times will degrade network performance by driving delivery to the lowest common denominator, and make the network less efficient. Adapting delivery to the predicted data delivery performance based on dynamic radio channel assessments promotes more efficient performance overall, across all users, even though at any single moment a network's site will distinguish between users based on channel quality.

The paper concludes that if adopted or expanded, several of the rules proposed in the NPRM would place constraints on mobile wireless networks that would stifle innovation and competition, negatively impact the user-experience and system capacity, and severely limit the ability of mobile wireless networks to meet the unique challenges faced by modern wireless networks. The result, in turn, would be harm to wireless users – the very outcome the Commission seeks to prevent.

From an engineering perspective, the concept that a network management exception to Open Internet rules is sufficient to allow wireless networks to evolve and operate is nonsensical. A modern wireless network must be managed aggressively. It is not an exception, it is a daily reality. Subjecting this type of network and network management to broad prophylactic rules with a vague "exception" standard would provide no clarity to carriers, edge providers, or consumers as to how these networks will be managed. The exception would either simply subsume any rules (e.g., blocking or non-discrimination) or providers would be stripped of their ability to evolve and manage networks for the betterment of the entire subscriber base.

This paper demonstrates the following:

- *Minimal regulatory constraints for mobile broadband networks would facilitate achieving higher spectral efficiency and improved user experience.*
- *Network Management is practiced extensively in mobile broadband networks and is critical for wireless operations.*
- *Preserving the ability for wireless carriers to block websites or applications as necessary for reasonable network management is important to avoid harm to the network or degradation and is critical to maintaining reliable and efficient service.*
- *Application of an anti-discrimination/commercial reasonableness rule to mobile broadband providers would hamper their ability to innovate, optimize, differentiate, and deliver high quality products and services.*
- *Expanding the transparency rule would increase costs and negatively impact network management option, but will not provide any meaningful benefit to consumers.*
- *Mobile broadband Internet Access service is an integrated information service due to the tight coupling between the device and the many network elements, needed for customized processing of different types of information, and the distributed nature of the complex wireless network.*

1. Overview

This technical paper demonstrates the unique technical aspects of wireless broadband networks that make the imposition of prescriptive net neutrality regulations highly problematic. Mobile broadband networks are highly dynamic, with constant changes in network standards, technology, and capacity needs. Mobile broadband operators are also managing their networks with limited spectrum resources, which must be managed actively and quickly to provide a high quality of service to consumers. As a result, wireless network management practices are necessarily complex. Further, congestion-related metrics are highly variable both temporally and spatially, and also change by the millisecond, making meaningful reporting impractical.

The 2014 Net Neutrality NPRM. With respect to mobile broadband service, the NPRM discusses the transparency rule, the no-blocking rule, and a revised anti-discrimination/commercial reasonableness rule. The existing transparency rule requires the service provider to disclose items such as network management practices and performance, though the FCC now seeks comment on whether and how to expand the transparency requirements for mobile wireless providers. The proposed no-blocking rule would prohibit mobile broadband service providers from blocking consumer's access to lawful websites and from blocking consumer's voice or video telephony applications that compete with mobile broadband service provider's services, though the NPRM seeks comment on whether to apply this rule more broadly to mobile wireless services. The NPRM proposes an anti-discrimination/commercial reasonableness rule that prohibits commercially unreasonable practices based on the totality of circumstances. The NPRM tentatively concludes that this rule should not be applied to mobile broadband service, but it seeks comment on whether to reverse that finding. Comments filed in response to the NPRM affirm the technical findings explained in this paper.

Mobile Wireless Networks Undergo Constant Technical Evolutions. Mobile wireless networks have evolved from first-generation analog systems to fourth-generation high-performance digital systems with multiple revisions within a given generation. These generations and revisions have widely different capabilities for both the networks and the mobile devices. Commercial mobile providers typically have multiple generations and revisions of generations simultaneously operating to serve legacy and new devices. Each time a new revision is introduced network management practices must change. The mobile broadband network and the mobile device perform numerous operations and interact with each other so that the end users have anytime and anywhere seamless communications experience. And the wireless industry has not reached the end of the road on innovation – the industry is already turning to the development of 5G technologies, injecting further complexity in the design and management of mobile wireless networks.

Mobile Wireless Networks Have Unique Technical Characteristics. The difficulty of quantifying guaranteed network performance and user experience is increased further due to the unique characteristics of mobile wireless networks. Examples of such characteristics include:

- scarcity of spectrum,
- dynamic radio channel conditions,
- the need to share radio resources among numerous users and user services with different Quality of Service (QoS) requirements,
- mobility,
- vast variability in loading due to both variations in user density per area and variations in usage and data rates,
- inherently complex process of network capacity growth, and
- integration of devices and network technologies with widely different data use and application capabilities.

These characteristics pose significant challenges to mobile wireless networks and make the imposition of the prescriptive net neutrality rules infeasible. In particular, determination of any reliable universal thresholds or metrics to quantify user experience or network performance is infeasible. Further, imposing such specific metrics would then distort optimization and would impose conditions that would degrade consumers' mobile experiences. Furthermore, mobile broadband providers need a high degree of flexibility to efficiently and effectively manage precious radio resources to ensure the best possible aggregate service experience for all subscribers.

QoS and the ability to treat different types of traffic differently based on their service needs are essential in a mobile network. In a mobile network, where the connectivity performance is not as stable as with a wired network, some services will simply not work well if they are not subjected to differentiated treatment. VoLTE is one example – it is meant to replace the traditional, circuit-switched phone service available on cellphones. Without prioritization of this traffic, the quality and reliability of the phone service would be severely impacted. Other future services such as LTE multicast have similar requirements. As new services are layered onto the networks, and historical separation of data and voice services vanishes the need to address QoS issues will only increase.

Wireless Operators Engage in Numerous Network Management Techniques. The network management practices in mobile wireless networks are extremely complex and consist of numerous mechanisms that are distributed among various components (or nodes) throughout the wireless and core network. Examples of network management mechanisms include the scheduling algorithm for downlink and uplink resource allocation, the handover algorithm, the load balancing algorithm, handling of the connected mode-idle mode transitions, adaptation to the changing channel conditions, power control, and interference coordination. These network management mechanisms are proprietary and are key competitive differentiators. Providers continually refine their network management practices to dynamically reflect changes in network equipment, application demands, and consumer usage patterns. Indeed, the rapid evaluation of these practices may well mean that by the time a given practice is challenged and adjudicated the practice may no longer be in use. Hence, a mandate to fully disclose these mechanisms, or to impose sweeping no-blocking or anti-discrimination rules, would discourage innovations, violate intellectual property rights, and harm consumers.

Wireless Network Operators Make the Most of Scarce Spectrum Resources. Wireless providers need maximum flexibility in the management of their networks to make the best use of the *scarce radio spectrum* in the presence of exponentially rising data traffic. Due to the scarcity of spectrum, innovative, high-performance, and ever-evolving network management mechanisms are absolutely essential to the overall network performance and user experience. For example, wireless providers must take steps to contain data-intensive applications from flooding the network with excessive amounts of traffic that would degrade service for many users. Wireless network operators require the flexibility to fairly balance network performance and user performance among users, devices, user services, and overall services on the network.

Net Neutrality Regulation Imposes Numerous Unique Challenges on Wireless Networks. As this paper demonstrates, application of the 2014 NPRM's proposed enhanced transparency rule to mobile wireless networks is nearly impossible, as network management practices are highly complex and are constantly changing. Furthermore, flexibility with respect to network management is essential to enable continued innovation in this area and these characteristics counsel strongly against far-reaching no blocking or anti-discrimination rules. Indeed, application of the no-blocking rule, meanwhile, is infeasible as the Commission has defined a "minimum level of service" that is not possible to guarantee for mobile wireless networks. The revised anti-discrimination rule is not intended to be applicable to mobile broadband service, and the findings of this technical paper strongly support this FCC conclusion. The FCC should continue to distinguish between mobile and fixed broadband with respect to the "no discrimination rule" and "anti-discrimination/commercial reasonableness rule." The dynamic and resource constrained (and at times, congested) nature of mobile wireless networks requires differentiation among users and user services to ensure a high quality of network performance and a satisfactory user experience.

Mobile Broadband Internet Access is an Integrated Information Service. Mobile broadband service is a highly integrated service that enables a subscriber to access a variety of services at once. The Commission itself observed that wireless broadband Internet access service offers a single, integrated service to end users that inextricably combines the transmission of data with computer processing, information provision, and computer interactivity. This level of integration requires cross-layer optimization in the network to ensure optimal network performance. Without the flexibility to actively manage their networks, mobile broadband providers will not be able to deliver integrated services at the level of quality that consumers have come to expect.

Recommendations. Due to the challenges faced by mobile network operators, which are outlined below, this paper recommends that the Commission:

- recognize that mobile wireless networks must be treated differently from other communications networks,
- strive for minimal regulation of mobile wireless networks to promote continued innovation, and refrain from applying far-reaching no blocking rules or an anti-discrimination/commercially reasonable rule,
- grant to network providers maximum flexibility regarding the design, management, and optimization of networks to serve consumers,
- refrain from establishing minimum performance standards (or metrics) for wireless networks, as these are impractical to define or enforce in the face of spectrum scarcity and variability, and
- ensure that proprietary and competitive network optimization and management processes are respected, which will ensure continued innovation and differentiation.

Flexibility in tuning and adapting the network management mechanisms to the fast-paced technology evolution, implementation of new features and uncertainty regarding the requirements of emerging applications or services urge that the network management mechanisms in mobile wireless networks should not be subject to broad disclosure, sweeping no-blocking, or anti-discrimination requirements. In other words, these network management mechanisms are intended, by their very nature, to optimize the aggregate performance for the benefit of all users. A focus on specific metrics may work to the detriment of the aggregate network performance and user experience. Conversely, reporting aggregate metrics will not reveal meaningful insights into specific instances.

2. Mobile Wireless Networks: Evolution, Network Architecture, and Operations

In order to fully appreciate the complexities associated with managing a wireless network and the difficulty of imposing an inflexible net neutrality framework, it is helpful to have an understanding of the rapid evolution of wireless networks and technology as well as the underlying architecture. In the more than 30 years that the wireless service has been provided to consumers, there has been a near-constant evolution of the underlying network. Section 2.1 summarizes this evolution of commercial mobile wireless networks. Section 2.2 illustrates the network architecture for the most popular 4G standard – Long Term Evolution (LTE). The wireless network and the mobile station (referred to as the user equipment or UE, mobile device, or handset device) perform numerous operations and interact with each other so that end users have anytime and anywhere seamless communications experience, processes which are quite different from wireline systems. Section 2.3 provides a glimpse of such operations and interactions.

2.1 Evolution of Mobile Wireless Networks

Mobile wireless networks have evolved from the first generation (1G) to the fourth-generation (4G) in just about three decades. Numerous 1G systems were used throughout the globe. Advanced Mobile Phone System (AMPS) is an example of the 1G system in the U.S. First generation systems were analog (radio air interface) in nature and offered primarily voice services. First generation systems evolved to second-generation (2G) digital systems. The 2G systems provided better voice quality and higher capacity compared to the 1G systems. Global System for Mobile communications (GSM), Interim

Standard-54 (TDMA), and later Interim Standard- 95 (IS-95 or CDMAOne) are examples of 2G digital systems engineered primarily for voice services used in the U.S. These digital systems evolved to '2.5 G' systems to better support low data rate uses, including GPRS for GSM, IS-136/EDGE for TDMA, and CDMA 2000 1X for CDMA. Due to expanding needs for wireless data at higher rates, third generation standards for mobile wireless networks focused on supporting data services more efficiently separated from voice channels. The 3G systems include a packet-switched core network to facilitate Internet access. Universal Mobile Telecommunication System (UMTS), High Speed Packet Access (HSPA), and 1xEvolution-Data Optimized (1xEV-DO as a CDMA derivative) are examples of true 3G cellular systems. The 3G systems support peak user data rates on the order of few megabits per second (Mbps). Finally, fourth generation systems such as Long Term Evolution (LTE) were developed to provide higher data rates (e.g., many megabits per seconds) and higher spectral efficiency. In addition, LTE would allow both data and voice to be provided in an integrated fashion using Internet Protocol (IP) for transport, also known as VoIP (Voice over IP). LTE is currently being deployed in the U.S. and around the globe and is expected to be the most dominant wireless standard for the near term. Mobile wireless networks will continue to evolve—indeed providers are already working on 5G—with future generations of technologies bringing new capabilities and challenges. It is key that this evolution and innovation be able to progress unfettered by restrictive regulation. Figure 1 depicts the evolution of mobile wireless networks.

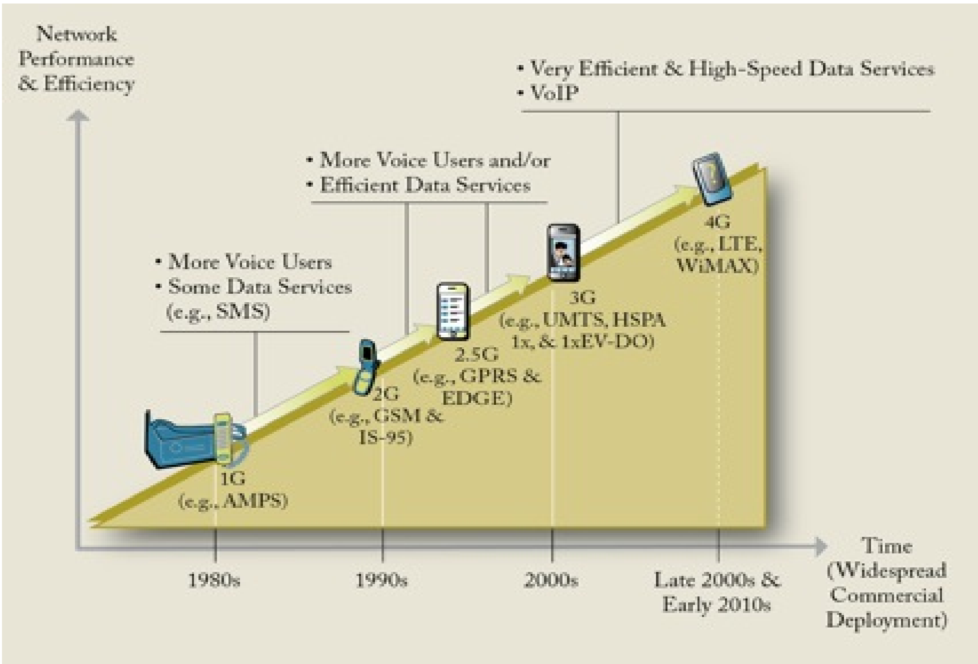

Figure 1. Ever-Changing Mobile Wireless Networks

Even for a given generation of wireless standards, multiple in-generation revisions that offer different features and capabilities exist. For example, 3G UMTS Release 99 supports a peak data rate of 2 Mbps in the downlink, while the 3G UMTS Release 5 feature called High-Speed Downlink Packet Access (HSDPA) supports a peak data rate of 14 Mbps in the downlink. The UMTS Release 7 feature called HSPA+ supports 21 or 42 Mbps in the downlink.

A mobile broadband provider typically has multiple revisions of multiple generations of technologies simultaneously operating. For example, in a given wireless service provider's network, some mobile devices may support GSM, some may support revisions up to HSDPA, some may support revisions up to HSPA+, and some may support revisions up to LTE. As the user switches from one generation of technology to another or from one revision to another, the performance can vary quite significantly. User mobility across different technologies needs to be properly managed by the mobile service provider. This involves complex network management.

The mobile service provider's network is never static. The network needs to be upgraded from one revision to another revision of a given generation technology and from one generation to another generation. Furthermore, once the network is upgraded with new features and capabilities, troubleshooting and then on-going optimization are carried out. The achievable peak performance keeps changing as the network undergoes never-ending upgrades. Even though LTE provides superior performance compared to prior generations of mobile wireless networks, LTE networks are currently undergoing upgrades with new features such as carrier aggregation and Voice over LTE (VoLTE), with each upgrade requiring changes to network management.

2.2 Network Architecture

The network architecture is different for 2G, 3G, and 4G (e.g., LTE) systems. This paper focuses on the network architecture for LTE due to its current dominance; however we will briefly describe simplified 3G and 4G network architectures below. In this section, we will describe the complex and decentralized nature of the wireless network and why application of net neutrality principles in this environment is so difficult. Moreover, with the move to an all IP-based infrastructure, the core wireless infrastructure is more intrinsically integrated into the radio network which in turn requires the wireless provider to calibrate and manage the radio resources and the core resources more carefully to ensure that subscribers are receiving an appropriate level of service.

LTE is defined by an organization or a standards body called the Third Generation Partnership Project (3GPP). 3GPP has defined a radio network called the Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) and a core network called the Evolved Packet Core (EPC). The combination of the E-UTRAN and the EPC is termed Evolved Packet System (EPS) that can be viewed as the end-to-end LTE network. The LTE EPS uses the help of auxiliary networks such as IP Multimedia Subsystem (IMS) and the Policy and Charging Control (PCC) to provide a variety of services to end users. We will look at the main functions of the E-UTRAN, EPC, IMS, and PCC after a brief discussion of the simplified network architectures of 3G (e.g., UMTS) and 4G (e.g., LTE) network architectures illustrated in Figure 2.

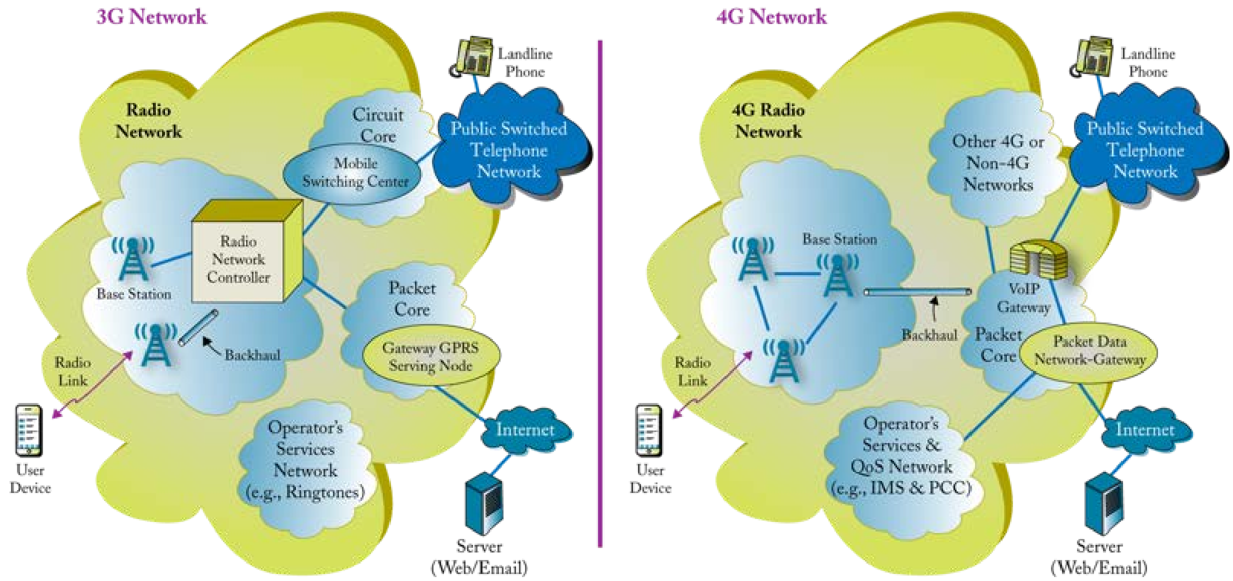

Figure 2. Simplified 3G and 4G Network Architectures

A 3G network consists of a radio network, a circuit-switched core network, a packet switched core network, and a services network. The radio network includes multiple Radio Network Controllers with each Radio Network Controller controlling hundreds of Base Stations. The Base Station communicates with the mobile device (referred to as the user device) via the air interface. The circuit-switched core network interfaces with the Public Switched Telephone Network so that the mobile device can communicate with a landline phone. The packet-switched core network enables the mobile device to access web and email servers via the Internet. The Mobile Switching Center is one of the nodes residing in the circuit-switched core network and controls the voice calls. The Gateway GPRS (General Packet Radio Service) Serving Node is an example of the packet-switched core network node and is in charge of assigning an IP address to the mobile device.

A generic 4G network consists of a radio network, a packet-switched core network, and a services and Quality of Service (QoS) network. The radio network includes the base stations. The packet switched network interfaces with the Internet using the help of a node such as the Packet Data Network Gateway. The packet-switched core network also interfaces with other 4G or non-4G networks. Since there is no circuit-switched core network in a typical 4G network, special nodes such as a VoIP gateway are needed to support calls between the 4G mobile device and the Public Switched Telephone Network. Auxiliary networks such as IP Multimedia Subsystem (IMS) and Policy and Charging Control (PCC) can be viewed as part of the operator's services and QoS network; these networks enable the service provider to offer to its subscribers a variety of IP-based services that have different QoS requirements. *We take a closer look at the LTE-specific 4G network architecture next.*

Wireless Radio Networks are Complex and Decentralized. The E-UTRAN has a decentralized and flat architecture. The E-UTRAN consists of the Evolved Node B (eNodeB or base station). The eNodeB communicates with mobiles over the wireless interface. The eNodeB makes the network management decisions related to the radio resource utilization. For example, the eNodeB evaluates the availability of the radio resources to determine if the subscriber can be offered services or not. The eNodeB implements a scheduling algorithm that allocates radio resources (radio bands and within one band, Resource Blocks (RBs)) to the active users based on numerous factors including the target quality of service (QoS) of the applications of users, the amount of data, the number of users and the types of the user applications vying for resources, the radio channel conditions of users, the capabilities of the eNodeB and the mobiles, and the available spectrum. The eNodeB executes the scheduling algorithm as often as every 1 millisecond (ms). The eNodeB also determines the type of multiple antenna technique and the combination of the modulation and coding scheme for a given mobile device to reflect the prevailing radio channel conditions for the mobile. The eNodeB also carries out load balancing and interference coordination with the neighboring eNodeBs. The eNodeB implements a handover algorithm that utilizes the measurement reports of the radio environment received from the user equipments (UEs) and makes a handover decision if appropriate.

The Core Network is Tightly Integrated with the Radio Network. The Evolved Packet Core includes several entities such as the Mobility Management Entity (MME), Serving Gateway (S-GW), Packet Data Network Gateway (P-GW), and Home Subscriber Server (HSS) with specific responsibilities assigned to these entities. The Mobile Management Entity authenticates the LTE subscriber by working with the Home Subscriber Server. The Home Subscriber Server stores the subscriber database including the authentication related information. The Mobile Management Entity keeps track of the mobile device location when the mobile is in the idle mode so that a page can be sent to the mobile device to bring it out of the idle mode. The Mobile Management Entity coordinates the setup of Evolved Packet System bearers[1] for a mobile device; the Evolved Packet System bearers help carry the user traffic between the mobile and the Packet Data Network Gateway. The Packet Data Network Gateway allocates one or more IP addresses to the mobile device. The Packet Data Network Gateway is a mobile's gateway to the outside world such as the Internet. The Serving Gateway helps move the traffic between the eNodeB and the Packet Data Network Gateway. When the mobile goes from one eNodeB area to another eNodeB area, the Serving Gateway learns about such user mobility from the Mobile Management Entity and is able to forward the traffic between the Packet Data Network Gateway and the correct eNodeB. When the user is receiving information from a web server, the IP packets from the web server pass through the routers in the Internet and arrive at the Packet Data Network Gateway. The Packet Data Network Gateway forwards the user traffic to the correct Serving Gateway. The Serving Gateway forwards the IP traffic to the eNodeB that is currently serving the UE. The eNodeB allocates suitable radio resources to the mobile device and sends the IP packets to the mobile over the air interface.

The End-to-End LTE Network is Carefully Calibrated to Provide Quality of Service to Consumers. The Evolved Packet System works with the IP Multimedia Subsystem (IMS) and the Policy and Charging Control so that subscribers can be offered a variety of IP Multimedia Subsystem-based services with suitable QoS. The QoS benchmarks are derived from the standards work in 3GPP and are not set by the individual wireless provider. Examples of IMS-based services include Voice over IP (VoIP), Short Message Service (SMS), and Instant Messaging (IM). The wireless service provider is aware of the IMS-based services of the subscriber and the signaling associated with the IMS-based services passes through the Evolved Packet System and the IMS network. The IMS network performs its own service authentication for the cellular subscribers to allow the subscribed IMS services. The IMS network processes the signaling messages and extracts QoS for a given IMS service. The IMS network specifies

[1] A bearer in this context refers to a "pipeline" connecting two or more points in the communication system in which data traffic flows. An "EPS Bearer" would be the pipeline through which data traffic flows within the Evolved Packet System.

such QoS to the Policy and Charging Control network, which compares the service-requested QoS with the subscribed QoS and determines the QoS and charging rules based on operator policies and user subscriptions. The Policy and Charging Control network uses the help of the Packet Data Network Gateway to initiate the setup of an Evolved Packet System bearer[2] to meet the QoS requirements of the subscribed IMS service. Non-IMS services such as regular email and web browsing use the best-effort Evolved Packet System bearer toward the Internet, and signaling and traffic for such non-IMS services do not pass through the IMS network. Once a suitable Evolved Packet System bearer is in place, the Policy and Charging Control and the Packet Data Network Gateway implement the negotiated service-specific QoS. Although the resource bottleneck is usually radio resources at the eNodeB, the QoS control is needed on the link between the eNodeB and the Serving Gateway and the link between the Serving Gateway and the Packet Data Network Gateway.

2.3 Typical Wireless Network Operations

The 3G and 4G mobile wireless networks are quite complex, with various mobile device and network operations combining to support high data speeds and ever-improving quality of service. Figure 3 provides examples of such operations of mobile devices and the network for LTE.

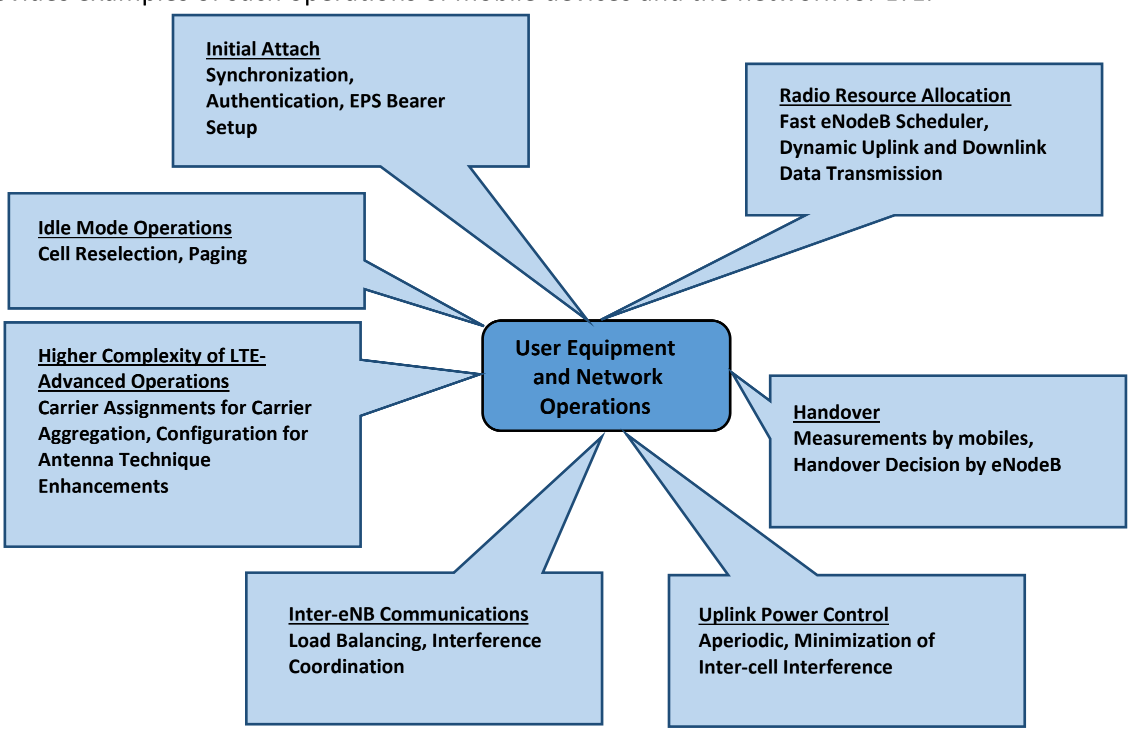

Figure 3. Operations of the Wireless Mobile Device and the Network

The mobile device carries out an initial attach procedure after power-up. During the attach procedure, the mobile achieves downlink and uplink synchronization with the eNodeB. The mobile and the network authenticate each other, and security is established. A default Evolved Packet System bearer with best-effort service is established toward a default packet data network to carry information without any

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[2] End-to-end QoS is controlled at the EPS bearer level in LTE. Hence, if two applications need two different levels of QoS, two different EPS bearers with distinct QoS characteristics are needed. Furthermore, two applications with same QoS needs can be placed onto the same EPS bearer.

guaranteed data rate but with the target delay of 300 ms between the mobile and the Packet Data Network Gateway. The mobile is typically allocated an IP address during the default Evolved Packet System bearer setup.

Active mobiles have one or more Evolved Packet System bearers, and, the eNodeB scheduler dynamically allocates radio resources to the mobile for the downlink data transmission and the uplink data transmission. The eNodeB scheduler executes as fast as every millisecond to adapt to the radio channel conditions and to modify the allocated downlink and uplink resources.

The serving eNodeB configures the active mobile with measurements of neighboring cells that can be on the same carrier frequency as the serving cell or a different carrier frequency, or a different radio access technology (e.g., UMTS). The mobile device provides measurement reports when configured measurement events occur. The serving eNodeB makes a handover decision (if appropriate) and works with the target eNodeB to obtain resources for the mobile. Handover may occur without the movement of a user if the handover would balance traffic between eNodeBs.

In addition to allocating spectrum resources to the mobile, the eNodeB also controls the transmit power of the mobile by sending power control commands. Power control in LTE may be implemented as aperiodic and multiple power step-up and step-down sizes can be used. Power control helps minimize inter-cell interference in the uplink.

The eNodeB may communicate with the neighboring eNodeBs to carry out load balancing and to coordinate interference. Minimizing interference improves the achievable user throughput and cell throughput. Scheduling provides a compromise between fairness in serving all users and throughput for the overall network.

Complexity of the LTE network increases further with LTE-Advanced. The eNodeB scheduler needs to decide when to use multiple carrier frequencies simultaneously for a given mobile to improve throughput as part of the carrier aggregation feature of LTE-Advanced. More antenna technique enhancements are available in LTE-Advanced compared to LTE, and, the eNodeB dynamically needs to determine the type and configuration of the multiple antenna technique.

In the absence of data activity for a configurable time period, the eNodeB asks the mobile to enter the idle mode. The network needs to keep track of mobiles in the idle mode so that the network can page the mobile in the correct geographic region for incoming voice or data traffic. Even though the mobile in the idle mode does not consume any radio resources, it performs cell reselection to observe the strongest cell so that it is in the best possible cell when it needs to exit the idle mode to do some activity such as signaling exchange or data transfer.

3. Characteristics of Mobile Wireless Networks and Differences Between Wireless Networks and Wireline Networks

In Section 3.1, the characteristics of mobile wireless networks are discussed in detail. These characteristics dictate the complexity of network management and the need for flexibility for wireless providers to respond to changing circumstances within the network. Section 3.2 describes the significant differences between wireless and wireline network architectures that warrant differences in how mobile wireless networks are managed.

3.1 Characteristics of Mobile Wireless Networks and Resulting Implications

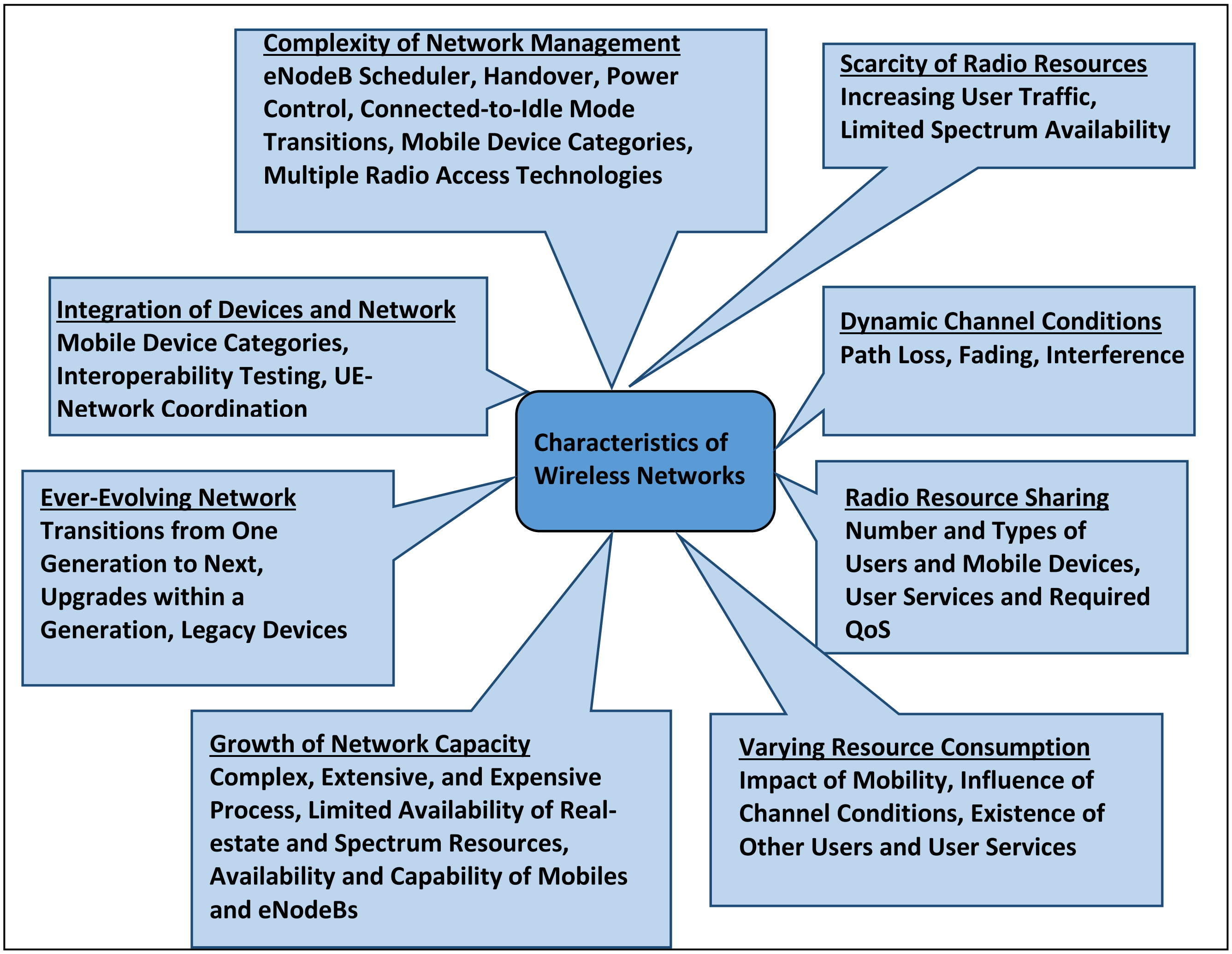

Figure 4. Characteristics of Mobile Wireless Networks

Figure 4 summarizes the characteristics of mobile wireless networks. These characteristics as a whole pose significant challenges to mobile wireless networks and make the application of prescriptive net neutrality principles to mobile wireless networks practically infeasible. In particular, determination of any reliable thresholds to quantify user or network performance is impossible. Furthermore, service providers need a high degree of flexibility to efficiently and effectively manage precious radio resources to ensure the best possible service experience for all subscribers.

Scarcity of Radio Resources. The popularity of the Internet and IP-based services such as video streaming have contributed to the explosion in the amount of data traffic traveling through the mobile broadband network. 4G services such as LTE bring with them higher data speed and greater video quality. The result has been more intensive use of 4G devices for bandwidth-heavy services, such as streaming video. Globally, in 2013 a 4G connection generated 14.5 times more traffic on average than a non-4G connection.[3] Although 4G connections represent only 2.9 percent of worldwide mobile connections today, they already account for 30 percent of mobile data traffic worldwide.[4] In the United States, the average 4G smartphone generated 1,739 MB of traffic per month in 2013, compared to 906 MB for non-4G smartphones.[5] Cisco estimates that "In the United States, mobile data traffic by 2018 will be equivalent to 383xthe volume of U.S. mobile traffic ten years earlier (in 2008)."[6] However, spectrum does not become available with the same growth rate as data traffic. Mobile broadband operators are constrained by the amount of spectrum available and the growth rate of new spectrum availability will not keep up with constant increases in user demand. This is exacerbated by the rapid rate of data intensive applications, now enabled by mass adoption of screen based smartphones and tablets that encourage use of pictures, graphics and video, and hence drive data demand as well as driving requirements for lower latency (real time response). Scarcity of radio resources, such as spectrum, necessitates efficient management of aggregate radio resources that needs to strike a balance among numerous competing factors such as the number of active users, target QoS of user services, and prevailing radio channel conditions.

Radio Resource Sharing. Limited radio resources must be shared among the active users in a given geographic area. Basically all of the channel capacity is divided among the various users and the speed for every user will go down as more users are added. A small number of very heavy data users using apps that are extremely data intensive can have a disproportionate impact on a large number of users. The eNodeB scheduler, as often as every millisecond, needs to consider a number of factors such as the number of active user devices, capabilities of these devices, capabilities of the eNodeB, prevailing channel conditions of different devices on the network, and target QoS of different services to determine the amount of radio resources for individual users. Even if best-effort service were the goal for all users, these users would typically experience different data rates as the eNodeB scheduler would try to improve overall network throughput and overall user throughput.

Dynamic Channel Conditions. For a given level of service quality, the required amount of radio resources is a function of the channel conditions, and the channel conditions not only vary over time, but also as a function of distance from the serving cell. The signal-to-interference plus noise ratio (SINR) directly influences the required radio resources. SINR is influenced by a variety of factors such as the propagation-based signal attenuation, the severity of fading (e.g., shadow fading and Rayleigh fading), and the amount of interference. Furthermore, the channel conditions hardly remain static. The channel conditions change due to factors such as user mobility. Network operators need maximum flexibility to manage radio resources to quickly adapt to changing channel conditions. Even to preserve a given data rate, the user may need 36 times more radio resources when the channel conditions degrade.[7] For

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[3] Cisco, Cisco Visual Networking Index, Global Mobile Data Traffic Forecast Update, 2013-2018 at 2 (Feb. 5, 2014) ("Cisco Feb. 2014 VNI Report"), available at http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.pdf.

[4] *Id.*

[5] Cisco, VNI Mobile Forecast Highlights, 2013-2018 at "United States – Accelerating Network Speeds" ("Cisco VNI Highlights"), *at* http://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country (last visited June 10, 2014).

[6] *See* Cisco VNI Highlights at "United States – 2018 Forecast Highlights."

[7] To quantify downlink channel conditions, the LTE standard has defined Channel Quality Indicator (CQI) that is a measure of achievable spectrum efficiency. CQI=1 corresponds to poor channel conditions, while CQI=15 corresponds to excellent channel conditions. The efficiency of transmission decreases from 5.5547 bits to 0.1523

example, a far-away user may require more coding (effectively more redundancy, meaning a higher real radio data rate to support the same effective data rate) and more retries (faulty packets with too high an error rate to be properly decoded are resent). Thus not all users are the same, even though their perceived data rates (the data rate the end user observes) appear the same. There are no definable metrics that could 'fairly' assess the achieved data rate. It takes the network effectively more network air interface resources (radio capacity) to serve such far-away (poor radio channel) customers. There is no such analogous situation for wired or fiber optic networks, because the channel quality conditions do not vary by such a large ratio, nor are the channel conditions so variable over time or space.

Varying Resource Consumption. Users in different channel conditions and using different services consume different amounts of resources. Even for the fixed throughput, different users would consume different amounts of radio resources depending upon the device-specific channel conditions. For a given channel condition, different services such as email and a VoIP call would consume different amounts of resources. It is nearly impossible to determine the exact amount of radio resources for a given user due to the highly dynamic nature of mobile wireless networks.

Challenges of Network Capacity Additions. Mobile broadband providers invest heavily to increase network capacity and keep up with rising user traffic and user expectations. Capacity can be increased by adding more spectrum (more different bands or more channels within the existing band(s)), deploying capacity-enhancing features such as advanced antenna techniques, and adding more cells (either by deploying 'split' macro cells or small cells) via cell-splitting techniques to gain more capacity via more 'frequency reuse.' In general, many of these techniques are quite expensive and take a long time from the concept to full commercial realization. Also, many of these radio capacity enhancing techniques have practical limitations. Deploying multiple bands requires replacing the users' handsets, and the costs rise as the devices are more complex to serve multiple bands. Base station cell splitting techniques cannot be implemented indefinitely because co-channel interference levels rise as the cells get smaller. Advanced antenna techniques require larger antenna arrays.

Thus, as noted above, mobile wireless broadband providers cannot simply build their way out of capacity constraints but instead are dependent on government allocation of spectrum resources and must purchase rights to use these resources at auction. Purchasing spectrum resources and implementing other capacity-increasing techniques can be quite expensive. Adding macro cells poses an additional challenge of finding real estate. To exploit the full potential of the standard, the user equipment and the eNodeB need to have compatible capabilities. It may take years before the commercial incarnations of user equipment and the eNodeB are coordinated and can deliver the target theoretical peak performance aimed by the standard. The intricacies of capacity growth along with ever-rising user traffic imply that efficient utilization of the existing radio resources is absolutely critical to the user experience and the network efficiency.

Ever-Evolving Network. As mentioned in Section 2, the mobile broadband service provider's network keeps changing to adapt to the newer generations of cellular standards and multiple revisions within a given generation of the cellular standard. The network has to manage the user equipment (UE) across various generations and revisions. As the newer standard emerges, the older standard does not

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bits for a given modulation symbol, leading to 5.5547/0.1523=36.4 more resources under the poor channel conditions to preserve a given data rate in poor and excellent channel conditions.

disappear immediately. Even the first-generation analog standard in the U.S., AMPS, survived for more than two decades! There are wide variations in achievable network performance and user-experienced QoS change among generations and even revisions within a generation. For example, a user may experience data rates of tens of Mbps (megabits per second) in an LTE network, but this speed could go down to hundreds of kbps (kilobits per second) when the user enters a UMTS network. Such wide disparity of the achievable performance makes it difficult to quantify even the minimum level of QoS or any metric (used for assessing performance and network neutrality) that relies on the apparent user experience.

Integration of Devices and Network. The user equipment and the network need to be tightly integrated to ensure satisfactory user experience. The standards typically define multiple categories of user equipment with different capabilities. Common ground needs to be found between a given category of user equipment and the eNodeB. In LTE, the network learns about the capabilities of the user equipment during the initial attach procedure and properly configures the equipment to ensure seamless communications between the device and the network. The network often works with user equipment of differing capabilities. Hence, even when two devices have identical channel conditions and identical allocation of radio resources, they could experience widely different throughput depending upon their capabilities as well as the proprietary aspects of the devices, such as antenna design. Extensive integration testing is carried out to ensure proper operations of user equipment and the eNodeB and error-free interactions between the device and the network. Tight integration between the user equipment and the network (e.g., eNodeB, Evolved Packet Core, and IMS) plays an important role in ensuring good user experience. Again, no 'fair' metrics could be defined to account for such differences in performance.

Complexity of Network Management. The network management in modern mobile wireless networks is extremely complex. Numerous interactions among the user equipment, the eNodeB, the Mobile Management Entity, the Serving Gateway, the Packet Data Network Gateway, the IMS network, and the Policy and Charging Control network occur to provide seamless communications experience and end-to-end QoS to the user. As mentioned in Section 2, the eNodeB scheduler allocates radio resources for the downlink and the uplink data transfer to achieve target QoS levels for the established Evolved Packet System bearers. The eNodeB executes a handover algorithm to choose the best possible serving cell for a user. The eNodeB also manages uplink power control commands to the mobiles to minimize inter-cell interference. The user equipment would be allowed to transmit more power if its uplink channel conditions are poor and/or its uplink throughput requirements are high. The eNodeB and the Mobile Management Entity manage connected-to-idle transitions for the user equipment. The network management must consider different capabilities of different mobile device categories to optimize the experience for the user. Ensuring seamless mobility across different radio access technologies is a non-trivial task. The network needs to configure the user equipment with suitable measurements and needs to connect radio networks supporting different radio access technologies. Integration testing within the network is also required to verify error-free coordination across radio access technologies. Nevertheless, this cross-layer optimization of the overall network is important for overall system performance and continues to be a promising area for further improving overall network performance.

3.2 Differences Between Wireline Networks and Mobile Wireless Networks

Any proposals to extend network neutrality principles conceived in a wireline context to mobile operations must contend with the vastly different technical challenges of these two types of communication networks. This section provides an overview of the differences in technical challenges between wireline and wireless systems as they relate to network neutrality regulation.

Wireless channels are quite different from wireline channels. First, the bandwidth for a wireless service provider might be on the order of 10s of MHz (~10^7 Hz) (5-30 MHz), but a fiber optic system could be 10s of GHz (~10^{10} Hz). The difference represents at least a one thousand-fold difference and in many cases is much greater in total bandwidth. The number of users or data rates that can be accommodated is directly proportional to the total bandwidth (and, in wireless systems, is also affected by the relative dispersion of the users within particular cells). Although 3G and 4G technologies can enable multi-megabit per second wireless transfer rates (assuming adequate spectrum resources), wireless systems will never have the bandwidth of wireline systems. A wireline network can exploit advances in optical fiber technologies to achieve extremely high bandwidth exceeding thousands of Gbps (gigabits per second). In contrast, the limited amount of radio spectrum in mobile wireless networks puts a severe constraint on the achievable data rates on a wireless link. Additionally, the wireline network is very consistent with respect to capacity capabilities of the channel over time (no fading) and space (low loss per distance of fiber). The wireline network engineer knows precisely how much bandwidth is available in a single fiber optic strand and (other than losses over distance) will have a near-constant understanding of the performance of the transport layer. In contrast, wireless networks are faced with ever-changing radio environments. Temporal issues such as multipath, clutter, blockage, channel fading, and extraneous interference will result in changes in the performance of the network and the quality of service experienced by subscribers. Also, the quality of the radio channel necessarily degrades rapidly as a function of distance from the serving cell. Without extensive management (and the inherent compensation mechanisms used within the radio air interface: variable rate coding, variable modulation, retry, etc.) of the wireless network to account for these transport layer issues, customers would not receive the types of services and data rates that they expect.

Moreover, a “build more infrastructure” approach is much less of a solution to capacity issues in wireless systems than in wireline systems for a number of reasons. First, spectrum constraints place outside limits that simply do not exist in wireline. Overall aggregate wireline bandwidth can be expanded infinitely by adding more cables or fibers, or by technology upgrades. Wireless bandwidth is ultimately constrained by fundamental performance limits, available spectrum and interference. Second, mobility and propagation issues combine to create much greater variability in the channel as compared to wireline channels. Third, mobility and propagation issues combine to create much greater variability in wireless traffic—the spread between peak and average traffic levels is typically much wider for wireless than wireline—which makes it infeasible to design networks to meet anything approaching peak demands. Fourth, issues unique to wireless networks are associated with deploying more capacity. Wireless carriers continue to spend billions of dollars annually on infrastructure upgrades, but they will continue to face severe capacity constraints, particularly with demand growing far faster than anticipated and faster than new bands can be added.

In wireline systems, in contrast, capacity improvements without the large expense of laying new fiber have been made possible through better technology at the fiber ends. Such technology options simply are unavailable for wireless systems, and dynamic prioritization and other management techniques are and will remain essential. While wireless network providers have taken efforts to use their spectrum resources more efficiency, such as by using small cell technology, as explained above wireless operators simply cannot "build out" of capacity constraints to the same extent as their wireline counterparts. In the 30 year history of commercial mobile networks, wireless providers have moved from analog (1G) to digital (2G) to 3G and now 4G services. However, each radio interface change requires substantial time and investment to bring about the gains in efficiencies expected from the more robust standards. Each base station must be updated via software and/or hardware to accommodate the changes in the air interface. All of the existing mobile devices in the network must be replaced to provide the full benefits to spectrum efficiency that the new radio standards allow. In contrast, wireline networks are able to upgrade solely at the edge of their networks to help gain efficiencies and do not require the extensive costs associated with wireless network technology migration to provide capacity gains. Fiber also presents extensive capacity availability throughout the network that has not yet been tapped for use, but is readily available for carrying traffic with updates to the technology at the fiber ends. Not only is the bandwidth of the wireless channel severely constrained compared to wireline channels, the reliability of the wireless channel is well below that of a wireline channel. The reliability issue is due to a number of factors, such as blockage of the radio signal (called shadowing), echoes or multipath of the signal, thermal noise, and, more importantly, interference. These impairments to the channel create substantial additional complexity and variability. Planning and operating a wireless deployment to ensure Quality of Service (QoS) and coverage is extraordinarily difficult because these impairments are random and unpredictable.

Interference is often the most important of these impairments, and, by its very nature, is constantly changing between and within cells. Interference occurs when multiple signals share the same spectrum. These signals are typically associated with the same service provider but are sometimes due to another service provider using the same or adjacent spectrum bands. Interference limits capacity in a wireless system on a dynamic basis, varying by location and from one millisecond to the next, and this problem has no counterpart in wireline systems.

Deployment and maintenance of wireline systems is less dynamic than wireless systems. Although wireline electronics and services continue to evolve, the advent of fiber has brought relative stability and efficiency to the wireline network architecture. In contrast, only change is constant in wireless standards and networks. As a result, network management practices must constantly evolve to address new architectures, new technologies, new standards, and new wireless applications with new performance needs.

These various features of mobile wireless networks make them much different than wireline networks. Table 1, below, summarizes the differences between wireless and wireline networks.

Table 1. Summary of Differences Between Wireless and Wireline Networks

Characteristic	Wireline	Wireless
Communications Channel	Relatively clean with signal Regeneration	Impaired with noise, interference, multipath, and blockage
Bandwidth	No spectrum limitations	Severe Spectrum limitations
Mobility	None	Constant, complex, often unpredictable, and often consuming extensive resources
Power	No need to manage power/battery life in wireline network for end user devices.	Limited power/battery on user device that must be accommodated through network management
Security	A lesser concern due to the physical path between the provider and the user (buried or on aerial infrastructure).	A greater challenge due to the possibility of tracking a user and variety of interfaces
Response to Increased Traffic Demand (i.e., the Capacity Problem)	Capacity increases may be feasible, although soaring demand and increasing congestion issues may call for additional pricing, bandwidth limitations, and prioritization mechanisms	Primarily managed dynamically through prioritization, scheduling, and power allocation
Network Complexity	Relatively simple	Extremely complex
Network Stability, Deployment, and Maintenance	Comparatively stable platform and systems, although high growth in demand and new applications are issues	Extremely dynamic platforms and systems; Deployment and maintenance require constantly dealing with real estate acquisition and zoning issues; Planning and maintenance are more difficult, and continuous maintenance and frequent resetting of network parameters is required; Infrastructure changes to address localized capacity issues can have ripple effects through adjacent cells

Characteristic	Wireline	Wireless
Quality of Service	Easier to implement due to availability of higher capacity and predictability of resource requirements	Quite difficult to implement due to variable capacity, unpredictability of resource requirements, and existence of proprietary mechanisms; Industry moving toward IMS and PCC

4. Challenges of Implementing the FCC's Proposed 2014 Rules on Net Neutrality to Mobile Wireless Networks

The NPRM seeks feedback on the *transparency rule*, the *no-blocking rule*, and the *anti-discrimination/commercial reasonableness rule* in the context of mobile broadband service providers. The NPRM proposes to apply the transparency rule to both fixed and mobile broadband wireless access. Regarding the no-blocking rule, the NPRM proposes to treat mobile and fixed broadband services differently. Furthermore, just as the FCC chose not to apply the 2010 unreasonable discrimination rule to mobile broadband service, the 2014 NPRM tentatively concludes that the replacement rule – or "anti-discrimination/commercial reasonableness" rule – would not be applicable to mobile broadband. Section 4.1 discusses the challenges of applying the enhanced transparency rule to mobile wireless networks. Section 4.2 describes the problems encountered while applying the enhanced no-blocking rule to mobile wireless networks. Section 4.3 briefly explains why the NPRM's view of not applying the unreasonable discrimination rule and the "anti-discrimination/commercial reasonableness" rule to mobile wireless networks is the correct approach. Extensions of the transparency and no blocking rules beyond those adopted in 2010 would be unwieldy and over-inclusive. Application of an anti-discrimination/commercial reasonableness rule to mobile broadband providers would hamper their ability to innovate, optimize, differentiate, and deliver high quality products and services.

4.1 Transparency Rule and Mobile Wireless Networks

The 2014 NPRM seeks comment on expansions of the transparency rule that would require mobile service providers to disclose information in several categories, including *network management practices*, *performance*, *congestion specifics (e.g., speed and packet loss)*, *peak load management*, and *parameters of default or best-effort service*. However, as explained below, for mobile providers there are numerous technical and practical problems in meeting these proposed expanded disclosure requirements that make implementation of any enhanced transparency rule problematic, resulting in increased costs, less responsive service due to limitations on network management and would not provide consumers with relevant or useful information.

4.1.1 Network Management Practices

In a typical wireline network, the only variable is the amount of traffic on a given link – all other things such as capacity, etc. are typically static. This makes management of the traffic relatively straightforward using standard queuing techniques (e.g. Weighted Fair Queuing) to ensure all customers receive a fair share of the available bandwidth during congestion caused by a small number of users.

With wireless networks, there are many variables that are all changing simultaneously – signal strength and interference affect capacity, orientation of antenna affects throughput, and obstacles can dynamically interrupt data, among other things. Using just standard wireline techniques would not work well in this environment, and as described below, there are many methods used to make the network function well. During times of congestion, heavy users may have to be treated differently based on multiple variables to ensure proper throughput for all users. This is something accounted for in the standards as well as in most network management practices, and requiring all these technically-driven capabilities to be suspended simply to ensure a "neutral" network can have significant negative consequences.

eNode B Base Station. The *network management practices* in mobile wireless networks are extremely complex and consist of numerous mechanisms that are distributed among various nodes in the network architecture illustrated in Section 2. The achievable radio network performance and user experience are influenced heavily by these network management mechanisms. Sections 2 and 3 identified several network management mechanisms implemented by the eNodeB such as the scheduling algorithm for downlink and uplink resource allocation, the handover algorithm, the load balancing algorithm, handling of the connected mode-idle mode transitions, adaptation to the changing channel conditions, power control, and interfere coordination. Although the standard defines auxiliary tools such as (i) measurement reporting by user equipment and (ii) inter-eNodeB signaling exchange via the standardized X2 interface, these network management mechanisms are proprietary to the infrastructure vendors. Infrastructure vendors differentiate their products based on abilities of these mechanisms. Hence, a mandate to fully disclose these mechanisms would discourage innovations, violate intellectual property rights, and harm both competition and consumers.

Core Network. Just like the network mechanisms implemented at the eNodeB, the network management mechanisms implemented in the Evolved Packet Core and the auxiliary networks of IMS and the Policy and Charging Control networks[8] could provide a competitive edge and serve to differentiate service providers. The load balancing among the Mobile Management Entities and management of idle mode mobile devices are examples of network management in the Evolved Packet Core that are vendor-proprietary. The service provider may have a specific way of providing a certain level of QoS for a given service by configuring the IMS and the Policy and Charging Control networks (e.g., certain target data rates and certain latency targets). Furthermore, the routers that carry signaling and user traffic between the eNodeB and the Evolved Packet Core and within the Evolved Packet Core may be configured by the implementation-specific network management framework.

Service providers need maximum flexibility in the network management of mobile wireless networks to make the best use of the *scarce radio spectrum* in the presence of the exponentially rising data traffic. For example, [Neel_MobileDataTraffic] reports that the mobile data traffic is expected to grow by a factor of 450 from 2005 to 2015. Furthermore, *scarcity of the radio spectrum* is clearly evident in Exhibit 11 of [Deloitte_SpectrumShortage], where the FCC estimates that the U.S. would experience a spectrum

[8] While we have mentioned examples of major network management mechanisms, we note that these are not the only mechanisms that exist. Numerous other algorithms that manage radio resources, core network resources, transport network resources, IMS and PCC resources exist. For example, some mechanisms to configure the operations of the radio channels and to coordinate resource utilization between macro cells and small cells would be needed.

deficit of 275 MHz relative to the demand in 2014. Due to the scarcity of precious spectrum, innovative, high-performance, and ever-evolving network management mechanisms are absolutely essential to the overall network performance and user experience. Flexibility in tuning and adapting the network management mechanisms to fast-paced technology evolution, implementation of new features and the uncertainty of the requirements of emerging applications or services require that the network management mechanisms in mobile wireless networks should not be subject to any disclosure requirements. In the fast-paced evolution of wireless standards, multiple revisions exist, as discussed above. Even for a given revision of the standard, the user equipment and the network vendors have multiple software releases to update. Revelations of the network management mechanisms in the eNodeB, the Evolved Packet Core, and the IMS and Policy and Charging Control networks would ultimately harm consumers due to a reduced rate of innovation resulting from adherence to counter-productive implementation of the transparency rule.

The situation is too complex to summarize with a small set of easily defined comparative metrics, and expansion to a more complex, detailed set of base station and/or network performance metrics would violate the confidential nature of the network providers' proprietary technical optimization choices. This would severely impact the pace of innovations in the area of network management.

4.1.2 User Experience and Network Performance

Performance is extremely difficult to estimate reliably for mobile wireless networks, because there are numerous factors that influence the achievable network performance perceived and user performance (user experience). To complicate the performance estimation further, many of these factors are dynamic. Also, many of these factors are application specific, in that they are more important for some applications than for others. As discussed in Section 3, the wireless network is characterized by a variety of factors including dynamic channel conditions, varying number of active users, differing QoS requirements for the services of active users, the available amount of spectrum, user mobility, the capabilities of user equipment and the eNodeB, the types of applications considered, and the generation and the revision within the generation of the wireless standards. All these factors together determine the network and user performance at a given instant. Furthermore, this performance would change from one instant to another as one or more factors change. Reporting average performance over a particular period of time may not make sense and could be misleading to consumers.

The achievable user throughput is a function of the signal-to-interference plus noise ratio, which is influenced by the radio channel conditions that reflect propagation-based path loss, type and severity of signal fading, and amount of interference. Signal-to-interference plus noise ratio, in conjunction with other measurements[9], also dictates the configuration of the advanced antenna techniques that can be used for a given mobile device at a given instant.

The number of active users and the specific QoS requirements of the services of these users determine how the available radio resources of the network are distributed. For example, in LTE one active user could get up to around 75 Mbps in a case of excellent channel conditions that are conducive to the use of spatial multiplexing technique. In contrast, poor channel conditions resulting from a weak signal (e.g., due to fading and large propagation path loss because the user is far away from the serving base

[9] Examples of these measurements include rank indication (RI) and precoding matrix indicator (PMI).

station) and strong interference may be able to support only about 1 Mbps.[10] If there are multiple active users with guaranteed bit rate (GBR) requirements, other users involved in non-GBR services such as email and web browsing will experience much lower average throughput. As noted above, the numerous variables inherent to a wireless network may mean that during times of congestion, heavy users may have to be treated differently to ensure proper throughput for all users. Should the FCC mandate the suspension of such network management practices in the name of "neutrality," significant negative consequences could result.

The throughput experienced by a user would also depend on the service (or application) being received by the user. A seemingly low instantaneous data rate of about 300 kbps would be more than adequate for a VoIP call, while a much higher instantaneous data rate (e.g., few Mbps) would be needed for video streaming or a file download to provide satisfactory user experience. In the absence of the context of the specific service or application and their related QoS requirement, a given value of data rate, or any other metric, such as latency, is not a reliable indicator of the user performance or experience.

The available amount of spectrum directly affects the achievable performance. If a service provider has a 10 MHz LTE channel in one market but only a 5 MHz LTE channel in another market, the achievable throughput can easily differ by a factor of more than two. The larger the channel bandwidth, the higher the achievable throughput. Frequency selective scheduling could provide larger gains in case of larger channel bandwidths.

The impact of user mobility on achievable performance is also significant. In general, a higher velocity of the user equipment results in a larger Doppler shift and typically implies frequent and more severe short-term fades. In contrast, a slowly-moving device (e.g., pedestrian speed) has a smaller Doppler shift and experiences fewer varying signal fades, but the time period for the fade may be much longer and more impactful, as the user may remain within a performance null area for a longer period of time. The signal-to-interference plus noise ratio required to achieve a target throughput (or error rate) can vary significantly due to the impact of the user mobility and the distance from the serving cell.

The network performance and the user performance are affected by the capabilities of the user equipment and the eNodeB. All the eNodeBs do not have support for all the configurations defined by the standard. For example, Release 8 LTE supports parallel transmission of data from four antennas. However, commercial Release 8 LTE deployments typically have two transmit antennas for parallel data transmission. Similarly, not all devices have these same capabilities. Five categories of user equipment are defined for release 8 LTE, and, Category 3 devices are widely used in current commercial deployments in the U.S. and around the globe. Category 3 devices receive signals on two antennas. Furthermore, Category 3 equipment supports QPSK and 16-QAM modulation schemes to transmit data in the uplink. In contrast, Category 5 devices have four antennas to receive the downlink signals and support QPSK, 16-QAM, and 64-QAM to transmit data in the uplink. Such differences in equipment categories are a key reason why the downlink peak data rate is around 300 Mbps for a Category 5 device and around 100 Mbps for a Category 3 device and the uplink peak data rate is around 75 Mbps for a Category 5 device and around 50 Mbps for a Category 3 device [3GPP_TS36.306].

[10] These calculations assume that a (2x2) MIMO (Multiple Input Multiple Output) technique is used when the channel conditions are excellent (i.e., with CQI=15) and a non-MIMO technique at CQI=1 is used.

The generation and the revision within the generation of the wireless standards also have a significant influence on the achievable performance. For example, Release 8 LTE supports theoretical peak data rates of 300 Mbps downlink and 75 Mbps uplink. In contrast, Release 10 LTE-Advanced supports a theoretical peak data rate of 3 Gbps downlink and 1.5 Gbps uplink. Again, defining one set of reasonable metrics is impossible in the face of different generations of handsets.

In summary, mobile broadband providers are committed to complying with the existing transparency rule but, recognizing that the specifics of network and handset performance will vary constantly, the granularity contemplated by the proposed expanded transparency rule would be infeasible. There are simply too many factors (most of which are highly dynamic or variable) that influence network and user performance, making it impractical to predict, guarantee, and/or verify user performance in the context of the expanded transparency rule.

4.1.3 Congestion

The 2014 NPRM envisions disclosure of congestion-related statistics such as speed (i.e., throughput) and packet loss. In the context of mobile wireless networks, such disclosure requirements are unhelpful for several reasons explained below.

First, the dynamic nature of mobile wireless networks leads to wide variations of throughput as discussed in Section 4.1.2 above. For data-centric systems, packet loss is reflected in the overall throughput. Furthermore, some throughput degradation and/or packet loss may not be due to congestion at all; it may simply be due to changes in channel conditions, user mobility, and/or service change. The packet loss rate may not really reflect any congestion.

Separating congestion issues from non-congestion issues through analysis and storing and maintaining such data for the sole purpose of compliance with the transparency rule would need significant investment of resources without any tangible benefit to consumers. As mentioned in Section 3, the eNodeB scheduler operates as fast as every millisecond, and the number of active users can change within a few seconds due to transitions between the idle and connected modes. So-called congestion can widely fluctuate in matter of few seconds. Network optimization processes aimed at addressing congestion can respond to these temporary congestion issues just as quickly. As a result, real-time disclosure of network congestion would be problematic to implement and confusing for consumers, as the network is constantly responding to ever-fluctuating levels of traffic. Section 2 illustrated the LTE network architecture. The complexity of the overall architecture means that network upgrades due to revisions or new feature implementations would almost certainly need extensive troubleshooting efforts which would likely lead to temporary congestion issues. Engineers seeking to comply with such a rule would face an unnecessary burden that could delay solutions to real problems, and cause harm to the subscribers instead of helping users (which is the real goal of the transparency rule). The key to keeping overall network capacity high is to adapt to the traffic over time using sophisticated and proprietary scheduling algorithms. Network neutrality rules which place strict demands on traffic handling and may restrict or prevent certain schedule techniques, would require infrastructure and capacity to be over-engineered to handle otherwise manageable peaks, and hence result in higher costs for consumers.

Since network optimization is an ongoing and iterative process, it is quite likely that some congestion issues that are reported will have been remedied long before they could be incorporated into any required disclosure. Mobile wireless networks have numerous challenges on the radio channel, and, service providers need to invest heavily in ongoing technology upgrades, network RF planning, design, and optimization activities. The technology for wireless is changing very quickly and will continue to change quickly for the foreseeable future. Service providers will have a learning curve to understand how to deploy this technology and realistically, regulatory policy will (and perhaps must) adjust more slowly to these technology developments. Undue regulation at this point will stifle technology deployment that could increase bandwidth availability and lower costs for the consumer.

4.1.4 Peak Load Management

There are many legitimate reasons why a wireless network operator needs to manage data traffic on its network. In such cases, reporting of such peak load management would have little benefit. Recall from Section 2 that the Policy and Charging Control network works with the Evolved Packet Core to ensure suitable QoS. Such interworking between the Policy and Charging Control network and the Evolved Packet Core means that peak load management of traffic may be carried out such that the QoS for a given Evolved Packet System bearer is met. Each Evolved Packet System bearer has QoS parameters such as the maximum data rate. If the incoming data rate exceeds the subscribed data rate, the Packet Data Network Gateway manages the data to meet the data rate constraint toward the Serving Gateway. Such peak load management is carried out as part of the 3GPP standard's QoS characteristics [3GPP_TS23.203]. The network needs to manage the traffic so that all users can satisfactorily receive services instead of just few users consuming disproportionate amounts of resources. If excessive amount of traffic is received at the eNodeB, the eNodeB may have to buffer the packets, delaying the packets and potentially causing packet loss if the device-specific buffer overflows. Hence, even for the user with higher data rate needs, suitable peak load management is needed.

The resources in mobile wireless networks are scarce, and these scarce resources must be shared among numerous users. If suitable optimization is not carried out, some applications could flood the network with excessive amounts of data traffic (and even signaling traffic), causing degradation to many users in the network. In general, higher data rates result in the consumption of more resources, and, concentration of radio resources among only few subscribers would be unfair to other users. Hence, network optimization could be viewed as a network management mechanism to provide some level of fairness among the uses and users of radio resources. Network operators need the flexibility of such legitimate management to strike a balance among fairness, network performance, and aggregate user performance. The network management in mobile wireless networks must have at its disposal all means, including optimization, to safeguard the interests of all subscribers and to provide the best possible experience to all subscribers instead of just a select few subscribers. This balancing is dynamic and load dependent, so again, one set of uniform metrics cannot meaningfully capture overall performance.

4.1.5 Parameters of Best-Effort Service

The NPRM asks if any parameters can be specified to quantify the best-effort service. Numerical parameter settings that quantify the best-effort service and that are reliable are difficult to guarantee in mobile wireless networks. First of all, commercial mobile wireless networks have a mix of radio access technologies, mobile devices with different capabilities, and eNodeBs with different capabilities. Hence, the achievable performance varies depending upon the specific combination of the technology, the mobile devices, and the eNodeB for a given channel condition.

Even within the narrow scope of a given standard such as LTE and ignoring differences among technologies, compliance with the NPRM-proposed transparency rule in the form of target parameters would be quite challenging. LTE defines nine levels of QoS in terms of QoS Class Indicators (QCIs) [3GPP_TS23.203]. A QoS Class Indicator (QCI) specifies the QoS class. Defining different data rates for these services offers operators additional flexibility. An operator could also define proprietary QCIs. For example, QCI = 1 is suitable for applications such as VoIP. Its priority is 2, and it seeks to provide a minimum data rate, e.g., around 12 kbps. (Of course, keep in mind that a wireless network cannot provide an absolute guarantee. “Guarantee” here means that if the network agrees to grant service with QCI = 1 for a user, it will try its best to honor the granted GBR (Guaranteed Bit Rate). In the worst-case, the call may drop due to a hostile radio environment.[11])

Now, let’s contrast QCI = 1 with QCI = 8. An application such as email might fall into QCI = 8. Since VoIP has more stringent delay requirements than email (e.g., 100 ms for VoIP vs. 300 ms for email), its priority is higher than email’s. Also, the target error rate for email is lower than that for VoIP because the integrity of email bits is much more critical than the integrity of VoIP bits. So our goal is to lose no more than one of one million IP packets for email.

A web browsing session typically uses QCI = 8 or 9, which corresponds to so-called best-effort service. However, according to the 3GPP recommendations, the Evolved Packet System bearer with QCI = 8 or 9 is a non-guaranteed bit rate (non-GBR) bearer and therefore has absolutely no guarantee of any minimum data rate. The maximum data rate for such Evolved Packet System bearer is operator-configurable. Commercial LTE networks determine the maximum data rate as a function of the mobile device category. Since there is no guarantee of any minimum data rate for the best-effort service, the most critical parameter (i.e., throughput or data rate) cannot be specified for the best-effort service. Furthermore, the priority of traffic associated with the best-effort bearer is the lowest among all types of Evolved Packet System bearers. Hence, when the eNodeB scheduler becomes busy serving higher-priority bearers, the average throughput can be expected to be impacted for the best-effort bearers.

In summary, the absence of the specification within wireless standards of even the minimum data rate for a best-effort service is a hurdle that cannot be overcome by the transparency rule.

In light of the practical issues described above in Sections 4.1.1 through 4.1.5, applying an enhanced transparency rule to mobile wireless networks is impractical, would stifle innovations, and (most importantly) would not benefit users at all. Even if some information about network management practices were to be disclosed to comply with the transparency rule, such information would most likely be too vague. Metrics for gauging network neutrality do not exist and if they did they would likely become obsolete quickly with the rapid development of technology and new applications. Enforceability of such a rule would be highly questionable and this rule would, in practice, reduce network performance.

[11] The packet delay is the one-way time between the device and the edge of the operator’s network. QCI = 1 aims for a delay of less than 100 ms. (The lower the number for priority is, the higher the actual priority.) The packet loss rate of 10^{-2} = 0.01 or 1% means that an application with QCI = 1 can tolerate the loss of one of 100 packets.

4.2 No-Blocking Rule and Mobile Wireless Networks

The *no-blocking rule* specifies that mobile broadband service cannot prevent consumers from accessing lawful websites and cannot prevent users from using voice or video telephony applications that compete with the mobile broadband service provider's services, subject to reasonable network management. The NPRM further clarifies that mobile broadband service providers would not be violating the rule if they do not degrade a lawful service or content below the minimum level of service. The NPRM is seeking a definition for such minimum level of service and exploring the feasibility of using measurements such as speed, packet loss, and latency delay to quantify the minimum level of service.

Application of the no-blocking rule has several unique challenges in mobile wireless networks. To begin with, the definition of the minimum level of service is not feasible for mobile wireless networks. Throughput is the most important performance metric for data-centric mobile broadband systems, and, as explained in Section 4.1.5 on the best-effort service, LTE does not define any minimum data rate guarantee for such service. Note that non-IMS applications such as consumer-chosen voice and video applications do not travel through the IMS network and are typically placed onto the Evolved Packet System bearer with QCI = 8 or QCI = 9. Recall from Section 2 that signaling for IMS applications such as operator-aware VoIP (e.g., Voice over LTE or VoLTE) travel through the IMS network and that the IMS and Policy and Charging Control networks work with the Evolved Packet Core to provide target QoS, which would include guaranteed bit rate (GBR) for QCI = 1 Evolved Packet System bearer. Hence, any non-IMS user application such as voice and video cannot be expected to have the IMS application-like QoS.

The issues associated with expansion of the no-blocking requirements for mobile wireless networks are similar to those addressed in Sections 4.1.1-4.1.5, above, for implementation of an enhanced transparency requirement. When a single user or single application could overwhelm the limited resources provided to wireless providers, such a provider must be able to block this interfering use to ensure the quality of service expected for many other users. As has been discussed throughout this paper, unlike wireline networks, mobile wireless networks have scarce spectral resources (capacity) that are affected by interference, multipath, blockage, clutter and other conditions which require active management, including blocking of particular applications or users. Without the ability to manage blocking effectively, a wireless provider would be faced with situations where a single user or application could occupy all the radio resources associated with a particular eNodeB – leaving any other subscriber seeking access to that eNodeB without the ability to connect and receive the service expected. Therefore, the current no-blocking regulation continues to be the most appropriate technical path forward. Attempting to apply a broader no blocking rule—even with a safe harbor set of guidelines or other means to cabin off "reasonableness" – is extremely impractical, as discussed in more detail below.

In case of resource crunch, the eNodeB gives higher priority to Evolved Packet System bearers carrying IMS signaling and guaranteed bit rate traffic (e.g., VoIP traffic). Furthermore, according to the Quality of Service Class Indicator characteristics defined in [3GPP_TS23.203], Evolved Packet System bearers are set with a certain Allocation and Retention Priority (ARP), and, by design, best-effort bearers have a lower Allocation and Retention Priority compared to other higher-priority bearers. The best-effort Evolved Packet System bearers carrying email, web browsing, and consumer-installed non-IMS voice and video applications could potentially be affected adversely as part of routine and legitimate network management.

Without the differentiation capabilities described above, the LTE network will simply not function reliably for some services, or will function in a very inefficient manner. Standards organizations such as 3GPP have spent years working out the details of these capabilities and how they will interoperate, and they should not be modified without thorough technical analysis.

The NPRM is seeking comment on the feasibility of using the following methods to define a *minimum level of service*: a best-effort standard, a minimum quantitative performance standard, and a reasonable person standard. As discussed in Section 4.1.5, a best-effort standard cannot be really quantified for mobile wireless networks. The minimum quantitative performance standard would also be impractical. Finally, the main problem with the reasonable person standard is that a typical end user cannot be expected to be knowledgeable about how mobile wireless networks operate and different people would have different expectations from their networks. The absence of reliable and quantifiable estimates of "reasonableness" makes the reasonable person standard highly subjective and non-enforceable. Wireless providers, based on network management requirements developed within industry standards, should have the right to block any use or application on their wireless network if such use would preclude other subscribers from accessing service. Attempting to limit wireless providers' ability to block (such as attempting to define "reasonableness") would not allow the scarce spectral resources available to wireless providers to be used in the most effective and efficient manner.

4.3 Unreasonable Discrimination Rule and Anti-Discrimination/Commercial Reasonableness Rule, and Mobile Wireless Networks

The FCC has stated that the newly-proposed anti-discrimination/commercial reasonableness rule, just like the original 2010 rule, is not intended to be applicable to mobile broadband service. Our view concurs with the FCC view that different treatment for mobile broadband should be continued because differentiation among users and user services is required to provide a satisfactory quality of service to consumers.

As discussed in detail in Section 3.1 above, wireless networks are characterized by: (1) scarce radio resources; (2) radio resource sharing; (3) dynamic channel conditions and varying performance; (4) varying resource consumption; (5) ever-evolving networks and (6) the need to integrate differing devices and infrastructure. Because of these factors, user differentiation due to the dynamic nature of the radio environment is fundamental to the operation of any good scheduling algorithm design for a wireless network. A good scheduling algorithm maximizes network performance while providing good user-perceived experience, not necessarily by treating all users or all applications identically. If the scheduler treats two users with two different channel conditions (e.g., one excellent channel and one poor/noisy channel) in the same manner, the overall network performance would certainly degrade and the average user experience would also deteriorate. Consider Figure 5, where two users are downloading an email with a huge attachment and their channel conditions are constantly changing. Good channel conditions can support a higher data rate, and poor channel conditions support a lower rate as illustrated in Scenario 1 and Scenario 2.

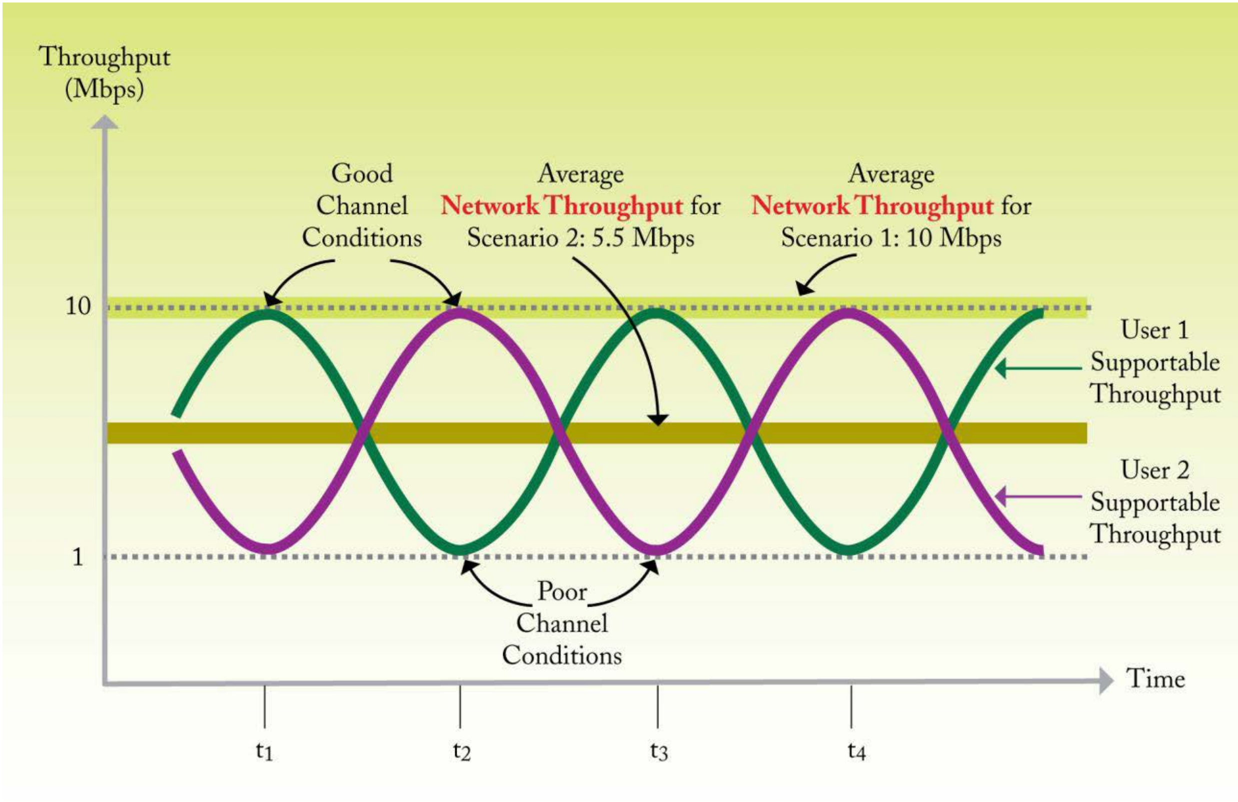

Figure 5. Necessity of User Discrimination Due to Dynamic Radio Environment

Figure 5 shows the user supportable throughput when all the available resources are allocated to the users. In Scenario 1, a high-performance scheduler allocates all the available resources to a user with the best channel conditions and transmits packets to such user. Observe that at time t_1, User 1 has the best channel conditions and can support 10 Mbps if allocated all resources. The scheduler dedicates the entire 100% of network resources to User 1 and sends a packet to User 1 at 10 Mbps at time t_1. At time t_2, User 2 has better channel conditions, and the scheduler allocates all network resources to User 2 and sends a packet to User 2 at 10 Mbps. The average network throughput is 10 Mbps as the network is always sending the packets at 10 Mbps. Sometimes the network sends packets to User 1, while other times, the network sends packets to User 2. The average user throughput that User 1 experiences is 50% of 10 Mbps = 5 Mbps, and the average throughput User 2 experiences is also 50% of 10 Mbps = 5 Mbps because these users are scheduled 50% of the time.

In Scenario 2, an equal-opportunity scheduler equally distributes the network resources at all times. At time t_1, the network allocates 50% of resources to User 1, leading to User 1 throughput of (50% of 10 Mbps = 5 Mbps). Note that User 1 throughput is 5 Mbps and not 10 Mbps because User 1 is allocated just 50% (and not all 100%) of resources. Similarly, at time t_1, the network allocates 50% of resources to User 2, leading to User 2 throughput of (50% of 1 Mbps = 0.5 Mbps). The network throughput at t_1 is 5.5 Mbps (User 1 throughput + User 2 throughput = 5 Mbps + 0.5 Mbps = 5.5 Mbps). Now, consider time t_2, where the allocation of 50% of resources to User 1 results in User 1 throughput of (50% of 1 Mbps = 0.5 Mbps) and the allocation of remaining 50% of resources to User 2 results in User 2 throughput of (50% of 10 Mbps = 5 Mbps). Again, note that the users experience only 50% of the throughput values shown in Figure 5 because the throughput values correspond to a hypothetical case where all of the network resources are allocated to a single user. The network throughout at t_2 is (User 1 throughput + User 2 throughput = 0.5 Mbps + 5 Mbps = 5.5 Mbps). The average network throughput is then 5.5Mbps. Let's calculate average user throughput. User 1 experiences 5 Mbps 50% of the time and 0.5 Mbps remaining 50% of the time, leading to the average user throughput of 2.75 Mbps (0.5*5 Mbps + 0.5* 0.5 Mbps = 2.75 Mbps). Similarly, the average user throughput for User 2 is also 2.75 Mbps. In other words, since the network equally distributes resources between the two users, the network throughput of 5.5 Mbps is equally divided between the two users as (5.5 Mbps/2 = 2.75 Mbps).

In our simple example, the network throughput is reduced by almost 50% (i.e., from 10 Mbps to 5.5 Mbps) in Scenario 2 compared to Scenario 1. Just imagine what would happen to the business models of service operators if the cost of supporting their customers doubles overnight? While the scheduler has optimized network performance in Scenario 1, User 1's throughput and User 2's throughput are also better in Scenario 1 compared to Scenario 2 (e.g., 5 Mbps in Scenario 1 compared to 2.75 Mbps in Scenario 2). Better network performance enables the service operator to cost-effectively provide services to many users simultaneously. Subscription plans for users can then be relatively inexpensive, promoting growth of cellular subscribers and services. The comparison of network performance in Scenarios 1 and 2 shows that differentiation is best for the aggregate network and for all users. Treating all users the same all the time appears more fair at first, but adapting to the radio channel by having the scheduler weight the service schedule against predicted data delivery performance results in better performance for everyone, even though at any moment, not all users are treated the same.

Combined service and user differentiation is also quite important. Assume that User 1 has an ongoing email application and has in the past been promised a maximum data rate of 10 Mbps, and assume further that all the network resources are being consumed by such a user. Suddenly, ten users start making voice calls. The network simply lacks the resources to simultaneously support ten voice users and an email user with a 10 Mbps data rate. If the network's resource management algorithms downgrade the email data rate to perhaps 9 Mbps, then the network can accommodate both the email user and all ten voice calls. If the network fails to differentiate between the voice users and the email user, all ten voice calls would be blocked. In summary, user and service differentiation is essential to aggregate service fairness for the average consumer. Here again, the scheduler is not treating every application identically ('fairly'), but the net aggregate result benefits more users. What set of metrics would represent this fairness? These considerations evolve as the applications mix changes.

Differentiation based on resource consumption is also inherent in a wireless network and facilitates network efficiency and fairness. The network management algorithms must differentiate between users based on the amounts of network resources each user is consuming. For example, current mobile wireless networks commonly limit the amount of resources a single user can consume. If one user consumes an excessive amount of network resources due to a hostile radio environment and/or such user is using bandwidth-intensive data applications, that user may dominate the network so much that no other user can get any service in the absence of pro-active network management.

There are several situations where it is legitimate and beneficial for wireless network operators to differentiate traffic. For example, Wireless technologies are increasingly being used for machine-to-machine services and public welfare systems. It is critical that these systems – such as, for example, wireless monitoring of bridges – be fully functional at all times, and this may require prioritization. In addition, public safety personnel clearly should have higher priority than regular users. More "ordinary" services, such as voice call, email, and streaming video, all require different quality of service levels, and wireless network operators should be allowed the flexibility to prioritize these diverse services in a manner that ensures that an end user experiences the quality of service necessary for these services to function. User and service differentiation is also essential to service fairness – one user should not be permitted to monopolize network resources at the expense of others.

In summary, the dynamic nature of mobile wireless networks requires a reasonable, necessary, and *dynamic*differentiation among users by the network management to ensure an acceptable aggregate quality of service for all wireless subscribers. To subject mobile broadband providers to claims that such non-uniform network management techniques are 'unfair' and violate commercial practices, particularly when combined with the prospect of regulatory rebuke, would significantly impair the ability of providers to experiment with new and innovative network management tools designed to improve consumers' experiences. Any rule that would prohibit discrimination on mobile wireless networks would be impractical and would actually work against the FCC's goals of promoting innovation and benefiting consumers.

5. Mobile Wireless Broadband Internet Access: An Integrated Information Service

Mobile broadband service is an integrated service that enables the wireless subscriber to access a variety of services in a wireless fashion. The subscriber's device communicates with the mobile broadband service provider's network via complex interactions. The nodes of the entire wireless network infrastructure work together to present a single unified view of the network to the subscriber's device and to provide service-specific QoS for a user's services according to the 3GPP LTE framework. All the network components need to do specific processing, which often needs to be customized for a given service, to provide seamless and satisfactory experience of a variety of services for the user. All the complexities associated with subscriber's experience of wireless services are handled by the subscriber's device and the broadband service provider's network without the active involvement of the subscriber.

When the FCC classified wireless broadband Internet access service as an "information service," it did so based on the correct finding that this service "offers a single, integrated service to end users, Internet access, that inextricably combines the transmission of data with computer processing, information provision, and computer interactivity, for the purpose of enabling end users to run a variety of applications."[12] This statement, which was made by the FCC in 2007, has only become more emblematic of the wireless ecosystem. As technologies and networks have evolved, subscribers are increasingly using advanced networks for multiple simultaneous data services, such as email, web browsing, and various other applications. Extensive and complex processing in the mobile broadband network allows customers to seamlessly navigate among multiple mobile broadband applications and services at the same time, enjoying a good experience of various applications.

The mobile broadband network consists of numerous network nodes that interact among themselves in different and complex ways and that do custom processing depending upon the type of service or application. Such interactions and custom processing enable the wireless subscriber to obtain an

[12] *Appropriate Regulatory Treatment for Broadband Access to the Internet Over Wireless Networks,* Declaratory Ruling, 22 FCC Rcd 5901, 5911 ¶ 26 (2007).

integrated information service that integrates different types of information to provide a unified service experience (user experience) and that meets specific requirements of applications (e.g., guaranteed data rate or very low packet error rate or very low latency). *Indeed, the mobile broadband service is an integrated information service that requires (i) tight coupling between the mobile device and the network,[13] (ii) numerous complex interactions[14] between the mobile device and the network and among the network components, and (iii) service-specific custom processing at different network nodes*.[15] Let's take a closer look at these three areas.

Tight coupling between the mobile device and the network is essential in providing seamless and satisfactory services to the subscriber. For example, each service requires a certain quality of service, and, the network properly configures the mobile device and the network nodes so that the user has satisfactory experience. According to the 3GPP LTE standard, the overall packet error rate cannot be greater than 0.0001% for services such as email and web browsing (see Table 6.1.7 in 3GPP TS 23.203). However, the raw packet error rate on the LTE air interface is 10%.[16] Hence, the network configures a suitable number of packet retransmissions to reduce the effective packet error rate from 10% to 0.0001%. Furthermore, the mobile device provides feedback on the prevailing downlink radio channel conditions so that the network can use suitable transmission parameters (e.g., the modulation scheme, the amount of redundancy, the type of multiple antenna technique, and the number of Physical Resource Blocks) to provide a satisfactory downlink data rate and hence a satisfactory user experience. Similarly, the mobile device informs the network about the amount and type of data it has in its uplink buffers and the available transmit power. The network allocates a suitable amount of uplink radio resources based on such information and the subscriber can send the data traffic (e.g., email) within acceptable delay limits (e.g., less than 0.3 second). This tight coupling enables end users to receive email, for example, at a data rate that would be expected with very limited errors. Without this network management, the quality of service would deteriorate and be unacceptable to subscribers.

Complex interactions between the mobile device and the network and among the network components take place before the subscriber can obtain even basic wireless services. Mobile devices typically do not have pre-assigned fixed IP addresses, and, the devices cannot obtain any IP-based services such as email and web browsing without IP addresses. Hence, the network *must* allocate an IP address to the mobile device. To provide security over the wireless interface, the network and the device first perform mutual authentication and then locally generate security keys. For example, LTE can secure the wireless interface by encrypting user traffic. The network also sets up several logical connections called Evolved Packet System bearers that help carry user traffic such as email and streaming video. The network

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[13] Such tight coupling is exemplified by packet retransmissions occurring between the user device and the radio network to provide essentially error-free information to the applications such as e-mail and web browsing.

[14] An example of such interaction is the invocation of a Domain Name System (DNS) server by the user device so that the name of a web site (e.g., www.cnn.com) can be translated into an IP address of the server that is in charge of the web site.

[15] An example of such custom processing include fast packet forwarding of delay-sensitive traffic by an IP router and delayed packet forwarding of delay-tolerant traffic by an IP router. The operator's network utilizes multiple IP routers within the network (e.g., between the Serving Gateway and the Packet Data Network Gateway in the LTE network).

[16] The LTE air interface uses the instantaneous target block error rate (BLER) of 10% to improve efficiency of precious radio resources. A suitable combination of the modulation scheme and Turbo coding is used to meet such target BLER for a given radio channel condition.

nodes interact among themselves and the network interacts with the mobile device so that the bearers can be set up. Selected information about the mobile device is stored at different nodes so that packets can reach the correct user via the bearers. Without all these integrated actions, the user would not be able to obtain the Internet services expected (i.e., would not be able to access the desired web site). The wireless provider must manage these complex interactions to provide the seamless experience expected by consumers.

Service-specific custom processing is carried out at different network nodes. Depending upon the policies of the service provider, different types of IP addresses could be allocated to the mobile device for different packet data networks. For example, for the packet data network of the Internet, an IPv4 address could be allocated to the mobile device because of prevalence of IPv4 addresses. In contrast, for IMS-based applications, an IPv6 address could be allocated to the mobile device to benefit from the abundance of IPv6 addresses. Quality of Service (QoS) in an IP network can be provided by an Integrated Services or Differentiated Services framework. The network node provides different QoS to different services to meet the service requirements and user expectations. When a Differentiated Services framework is used, Differentiated Services Code Point (DSCP) is used to mark each IP packet. IP routers use correct packet forwarding treatment to an incoming IP packet. For example, assume that two IP packets arrive at a Packet Data Network Gateway: a delay-sensitive IP packet carrying a streaming video and a delay-tolerant IP packet carrying email. The delay-sensitive IP packet carrying a streaming video can be marked with the DSCP value of 30 and the delay-tolerant IP packet can be marked with the DSCP value of 0. In case of heavy traffic, the IP routers between the Packet Data Network Gateway and the Serving Gateway would quickly forward the delay-sensitive packets (i.e., video streaming packets) and would delay the forwarding of the delay-tolerant packets (i.e., email packets). The IMS and the PCC network nodes also work with one another such that the bearers can help meet different QoS requirements for different services. This in turn allows the wireless provider to ensure that subscribers that are not affected adversely by latency to be delayed, while those applications that are latency sensitive are not delayed. For example, video streaming would not be delayed so that playback is acceptable for a subscriber, while email packets could be marginally delayed but consumers would not be affected by this delay. This network management allows the provider to manage the scarce spectrum resources in an efficient, effective manner, without degrading the subscriber experience.

Close cooperation between the mobile device and the network is needed for cohesive and seamless integrated service experience for the wireless subscriber.

Examples of Integrated Wireless Broadband Services

The tight integration needed to provide wireless broadband services is demonstrated below by how a consumer obtains two services, web browsing and video conferencing. For both of these cases, the mobile device and the broadband network must work together to provide a seamless and integrated service experience for the consumer. Before any services are rendered to the consumer, the mobile device synchronizes with the radio network and performs an attach operation with the network. As part of the attach operation, mutual authentication occurs, and security between the mobile device and the network is established. Furthermore, two default bearers are established, one for the Internet packet data network and one for the IMS Packet Data Network. The Packet Data Network Gateway allocates to the mobile device an IP address for the Internet Packet Data Network and a separate IP address for the IMS Packet Data Network. Additionally, IP addresses of the DNS server and the IMS server are conveyed to the mobile device. When the consumer initiates video conferencing, additional bearers[17] are established to carry voice and video through numerous interactions among the mobile device, the radio network, the core network, the IMS network and the PCC network. Now that all the groundwork for data traffic has been completed, the IP packets for the email and video conferencing packets start flowing through the network and the consumer reaps the benefits of all the hard work that the mobile device and network nodes have been doing.

<u>Web Browsing on Mobile Broadband Networks</u>

Let's summarize the *major steps involved when the consumer is browsing the web* as illustrated in Figure 6.[18]

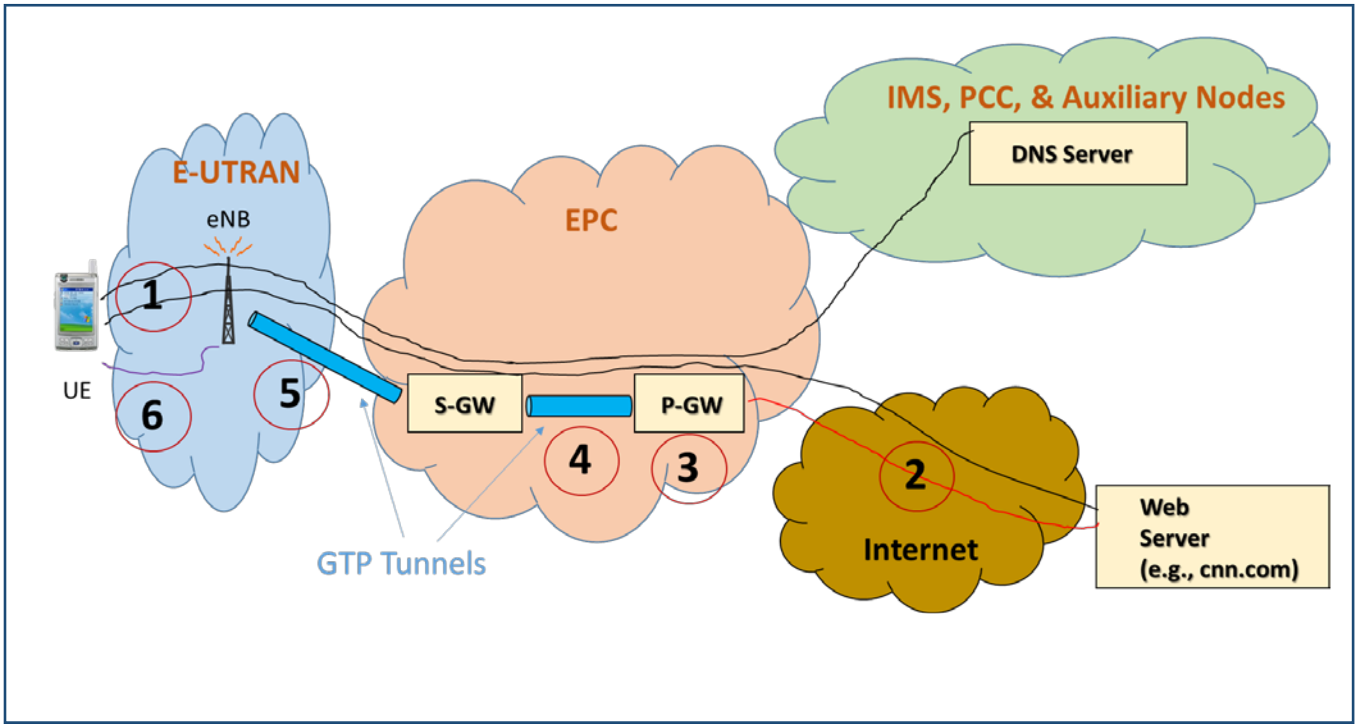

Figure 6. Major Communication Steps for Web Browsing

When the consumer selects www.cnn.com as the web site for browsing in Step 1, the mobile device communicates with the DNS server to find the IP address of the web server in charge of www.cnn.com and then communicates with the web server to set up an end-to-end connection with the web server. In Step 2, the web page from the web server passes through the IP routers of the Internet and arrives at the Packet Data Network Gateway. The Packet Data Network performs translation between the public IP address and the private IP address (if needed) in Step 3. In Step 4, the Packet Data Network

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[17] LTE controls QoS at the levels of the EPS bearers. Hence, two bearers are required for two services that need two different QoS levels.

[18] The simplified description here represents one possible approach for providing web browsing and video conferencing services. The LTE standard is quite flexible and operators can choose a variation of the approach described here to offer services to the user. In the interest of simplicity, only selected nodes and connections are shown in the figure.

determines the correct bearer for the incoming IP packet containing the web page and places the IP packet inside a tunnel (representing part of the bearer) toward the Serving Gateway using a protocol called GTP.[19] The Serving Gateway extracts the IP packet and places it inside another tunnel toward the eNodeB using GTP protocol in Step 5. The eNodeB uses several protocols of the air interface protocol stack to format the original IP packet for air interface delivery (including encryption for security) in Step 6 and then transmits the web page packet over the air to the mobile device. In Step 7, the mobile device also uses the protocols of the air interface protocol stack to extract the original IP packet from the air interface (including decryption) and then presents the web page to the consumer. *As is evident from these steps, the mobile broadband network nodes and the mobile device work closely together to present web browsing to the consumer as an integrated information service*.

Video Conferencing on Mobile Broadband Networks

Figure 7 summarizes the main steps involved when the consumer is participating in video conferencing [Radisys_October2012] [Ericsson_ Feb2012].

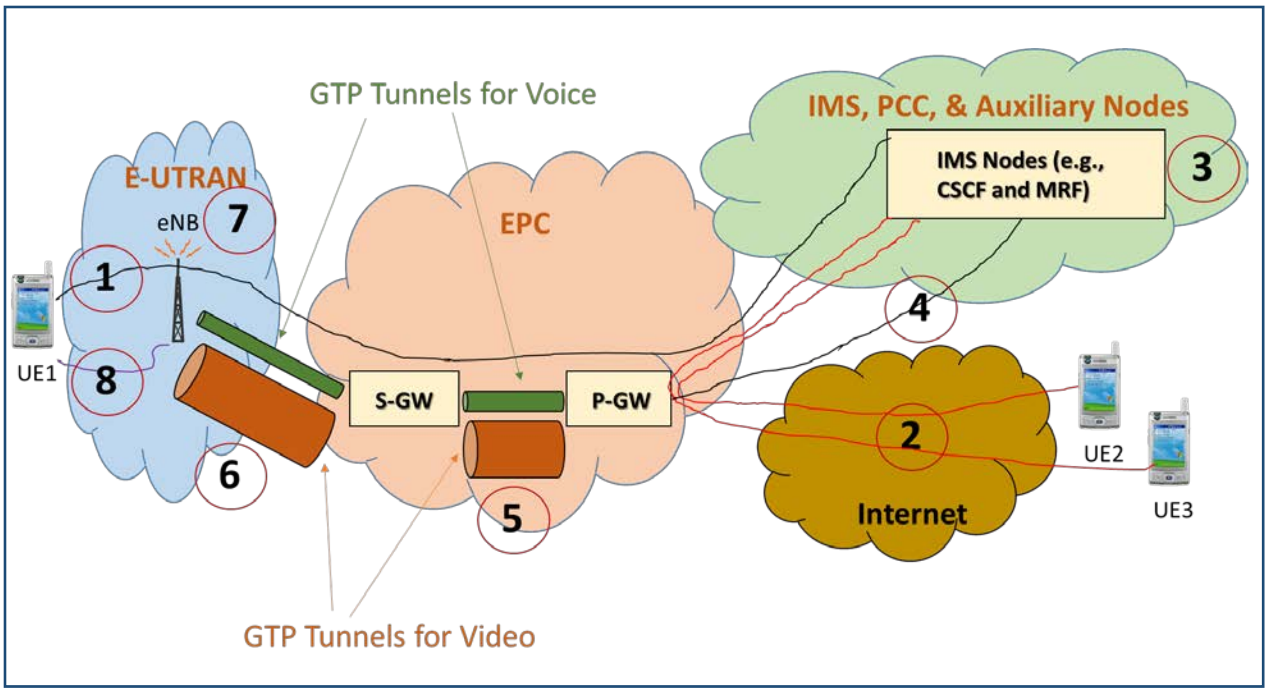

Figure 7. Major Communication Steps for Video Conferencing

19 GTP stands for GPRS Tunneling Protocol, where GPRS is General Packet Radio Service. GTP enables LTE to support IP mobility, where the user can move from one geographic location to another while maintaining the same IP address. IP mobility is one of key elements of a mobile broadband service.

When the consumer chooses a video conferencing application in Step 1, the mobile device 1 communicates with the IMS network to create communication paths among the participating devices. In Step 2, the voice and video media from other devices such as mobile device 2 and mobile device 3 arrive at the Media Resource Function in the IMS network. The Media Resource Function properly mixes the voice and video media streams (and performs media codec conversion if needed) in Step 3. In Step 4, the Media Resource Function sends the IP packets containing voice and video to the Packet Data Network Gateway. The Packet Data Network Gateway in Step 5 determines the correct bearers for the incoming IP packets, places the voice packets inside one tunnel toward the Serving Gateway using GTP, and places the video packets inside another tunnel toward the Serving Gateway using GTP. The Serving Gateway extracts the IP packets and places them inside other tunnels toward the eNodeB using GTP in Step 6. The eNodeB uses several protocols of the air interface protocol stack to format the original voice and video IP packets for air interface delivery in Step 7 and then sends these IP packets over the air to the mobile device in Step 8. In Step 9, the mobile device 1 uses the help of the air interface protocols to extract the original voice and video packets from the air interface and then plays voice and video to the consumer in the video conferencing application. *As is evident from these main steps, the mobile broadband network nodes and the mobile device work very closely together to offer video conferencing to the consumer as an integrated information service*.

See Appendix I for a more detailed discussion of how the mobile broadband network provides an integrated information service to subscribers.

6. Recommendations

Mobile wireless broadband networks face unique challenges such as the scarcity of spectrum and other radio resources, dynamic radio environment, varied and changing technologies for devices, base stations, and networks, differentiated and evolving services and applications, and exponentially-rising data traffic. Based on the in-depth analysis of the modern mobile wireless networks, we respectfully recommend the following to the FCC.

- ✓ Mobile wireless broadband networks must be treated differently from other communications networks such as fixed wireless networks and wireline networks.
- ✓ Aim for minimal regulations for mobile wireless networks to promote innovations and thereby facilitate achieving the ultimate goals of superior network and spectral efficiency and excellent user experience.
- ✓ Give maximum flexibility to the design and optimization of complex and distributed wireless network management so that the networks operate with maximum possible efficiency under the constraint of limited spectrum.
- ✓ Refrain from establishing any minimum performance standards, because these standards are simply impractical to define or enforce in mobile wireless networks.
- ✓ Ensure that proprietary and competitive management processes are respected and encouraged to motivate continuing innovation and differentiation.

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Appendix I

A Closer Look at the Mobile Broadband Internet Access Service

as an Integrated Information Service

Let's dive into the details of how the mobile broadband network provides an integrated information service to the subscriber.[20] Consider Figure 8, where the wireless subscriber is using an LTE network for three simultaneous services- web browsing, email, and video conferencing.[21]

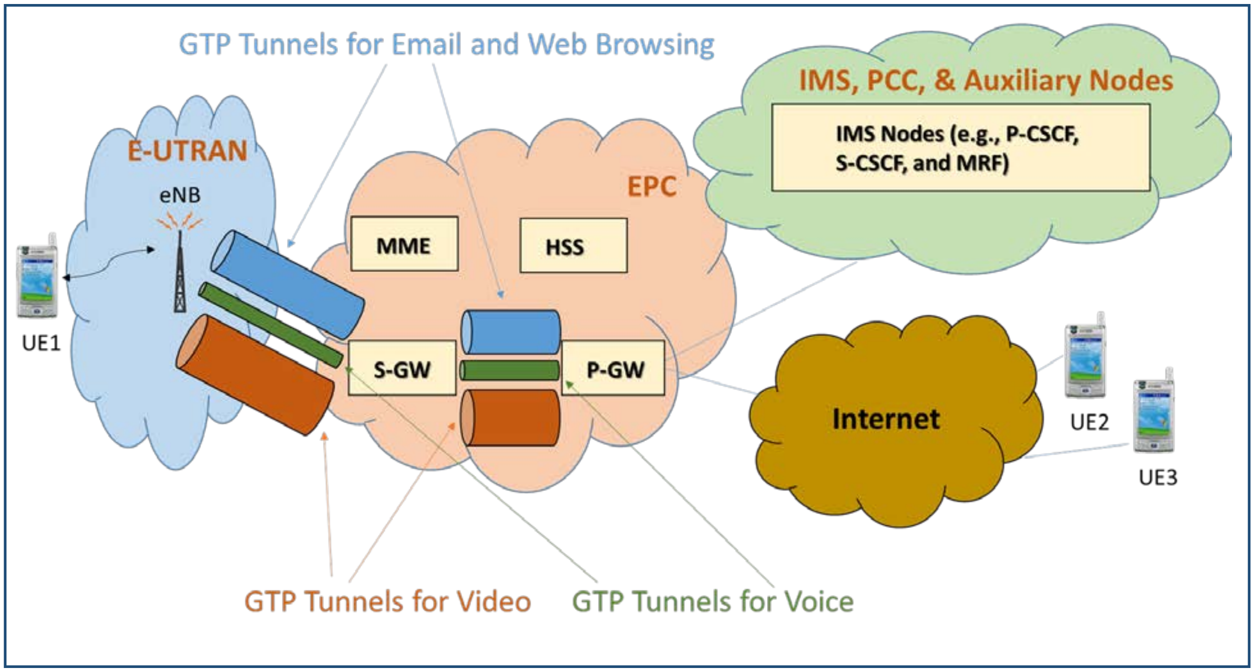

Figure 8. Integrated Information Service Offered by the Mobile Broadband Network

Different network nodes process different aspects of signaling and/or traffic. The following steps are executed to provide the integrated information service to the wireless subscriber: (I) initial attach and default EPS bearer setup toward the IMS network, (II) default EPS bearer setup toward the Internet, (III) dedicated EPS bearer setup toward the IMS network, and (IV) data transfer. Let's take a closer look at these steps below. *These steps show that complex interactions and node-specific custom processing are instrumental in providing an integrated information service experience to the wireless subscriber*.

<u>Initial Attach and Setting up of the Default EPS Bearer Setup toward the IMS Network</u>

As summarized in Section 2.2, the UE carries out the initial attach procedure upon power-up. The UE synchronizes with the eNB and establishes an RRC (Radio Resource Control) signaling connection with a cell. This RRC connection helps the UE and the eNB exchange signaling messages such as the messages

[20] The description given here is one possible implementation. The LTE standard is quite flexible and the operator can choose a variation of the approach

[21] This figure is based on the information given in [Ericsson_February2012] and [Radisys_October2012].

related to handover and EPS bearer setup. The UE and the MME perform mutual authentication. The HSS helps the MME in the authentication process. The signaling connection between the UE and the MME is a NAS (Non-Access Stratum) connection, which can be used for messages such as EPS bearer setup messages. Security is activated for the RRC connection and the NAS connection. The responsibility of securing the air interface between the UE and the eNB lies with the UE and the eNB. The responsibility of securing the NAS signaling connection between the UE and the MME lies with the UE and the MME. The service provider determines which packet data network should be used as the default packet data network. In Figure 6, the Internet and the IMS network are potential candidates as the default network. In our scenario, the network establishes a default EPS bearer with QCI = 5 (which is recommended by the 3GPP [3GPP_TS23.203]) that has the highest priority among the QCIs. During the default EPS bearer setup, the P-GW allocates an IP address to the UE, and, this address is conveyed to the UE by the MME. The MME also conveys to the UE IP addresses of the P-CSCF (Proxy- Call Session Control Function) and the Domain Name System (DNS) server. The P-CSCF is the first point of contact of the UE with the IMS network and performs various functions such as compression of SIP signaling messages and interactions with the PCC to provide end-to-end QoS for IMS-based services. The DNS server is used by the UE to resolve the website names to the IP addresses so that the UE can exchange IP packets with websites. The default EPS bearer toward the IMS network helps the UE and the network exchange SIP signaling messages.

Setting up of the Default EPS Bearer Setup toward the Internet

After the default EPS bearer with the default packet data network (e.g., the IMS network in our scenario) is set up, a different default EPS bearer with QCI-8 or 9 toward the Internet is established. The P-GW allocates an IP address to the UE for the Internet access. This default EPS bearer helps carry traffic corresponding to applications such as email and web browsing.

Setting up of the Dedicated EPS Bearers toward the IMS Network

As discussed earlier in Section 3, LTE controls the QoS at the level of EPS bearer. Although a default EPS bearer toward the IMS network has already been established, the QoS of this EPS bearer is inadequate to carry voice and video traffic. The QCI = 5 EPS bearer is a non-GBR bearer, while the voice and video need data rate guarantees for satisfactory user experience. When a user initiates video conferencing, SIP signaling messages are exchanged between the UE and the IMS network. The P-CSCF observes such signaling messages and conveys the information about the QoS requirements of the call to the Policy and Charging Rules Function (PCRF). The PCRF consults Subscription Profile Repository to check if the QoS requested by the video conferencing application can be accepted. The PCRF translates the generic QoS description extracted from SIP signaling messages into the LTE-specific QoS parameters (e.g., a numerical values for QCI and determination of the GBR) and conveys the LTE-specific QoS to the Policy and Charging Function (PCEF). According to 3GPP, P-GW acts as the PCEF. The P-GW initiates the setup of (i) the dedicated EPS bearer that can carry the voice traffic with suitable QoS and (ii) the dedicated EPS bearer that can carry the video traffic with suitable QoS. The S-GW conveys the dedicated EPS bearer requests to the MME. The MME works with the eNB and the S-GW to set up network resources for the new dedicated EPS bearers. The eNB accepts the dedicated EPS bearer requests if it has adequate radio resources to support the QoS required for the video conferencing service.

The IMS network, and in particular, the Media Resource Function (MRF) plays an important role in supporting the video conferencing service. The MRF consists of the signaling entity called Media Resource Function Controller (MRFC) and the user traffic entity called Media Resource Function Processor (MRFP). The MRFC works with other IMS entities and facilitates the establishment of communication paths among the devices that are participants of video conferencing. The MRFP is responsible for mixing voice streams and video streams so that the mobile device can receive audio and video from all other participants.

Data Transfer

Consider the web browsing service. When the subscriber enters the website name in the browser (e.g., Internet Explorer or Chrome), the mobile device contacts the DNS server to receive the IP address of the website. The mobile device and the web server can now exchange IP traffic such as web pages and acknowledgements to the received IP packets. The IP packets containing the web page from the web server pass through the Internet routers and arrive at the P-GW that gave the UE the IP address associated with the Internet. In case a private IP address had been assigned to the UE, the P-GW translates the public IP address into a private IP address for the journey of the IP packet within the operator's LTE network. The P-GW places the IP packet on the GTP tunnel (associated with the default EPS bearer for the Internet) toward the S-GW. The S-GW removes the IP packet from the P-GW side of the GTP tunnel and places the IP packet on the GTP tunnel toward the eNodeB. The eNodeB extracts the IP packet and passes it through these protocols of the air interface protocol stack so that IP packet is in the format that can survive the hostile and dynamic radio environment- Packet Data Convergence Protocol,[22] Radio Link Control,[23] Medium Access Control,[24] and Physical Layer.[25] The eNodeB then transmits the formatted IP packet over the air. The mobile device acquires the formatted IP packet from the air interface and recovers the original IP packet by using the air interface protocols. Finally, the IP packet is made available to the web browser that displays the actual content to the subscriber.

Let's focus on the video streaming service now. After the video conferencing service has been initiated and the IMS network has helped establish communication paths among the participants, the voice and video traffic can start flowing. Voice and video streams from the participants of the video conferencing arrive at the MRF. The MRF mixes the audio and video streams of the participants and sends the IP packets carrying voice and video to the P-GW. The P-GW has two dedicated bearers with the UE in support of video conferencing, one for voice traffic and one for video traffic. The IP packets containing voice are placed onto the tunnel associated with the voice traffic and the IP packets containing the video are placed onto the tunnel associated with the video traffic. Once the S-GW retrieves the IP packets from the P-GW side of the tunnels, it removes the IP packets from the P-GW side of the GTP tunnels and places the IP packets on the GTP tunnels toward the eNodeB. The eNodeB extracts the IP packets and passes them through the layers of the air interface protocol stack mentioned above. The eNodeB then transmits the formatted IP packets over the air. The mobile device retrieves the formatted IP packets from the air interface and recovers the original IP packets carrying voice and video by using the air

[22] Example functions of Packet Data Convergence Protocol are encryption and header compression.
[23] Example functions of Radio Link Control are in-sequence delivery of packets and retransmissions of erroneous packets.
[24] Example functions of Medium Access Control are scheduling and management of radio resources and control of physical layer retransmissions.
[25] Physical Layer takes care of functions such as modulation, coding, power control, and multiple access.

interface protocols. Finally, the IP packets are sent to the video conferencing application that plays the voice and video content for the subscriber.

The transport network that carries the traffic between eNB and the S-GW and between S-GW and the P-GW also needs to provide different QoS treatments to best-effort traffic such as email and web browsing and delay-sensitive traffic such as voice and video packets. The mechanism such as Differentiated Services (DiffServ) is widely used for QoS in an IP network. DiffServ involves marking of the IP packet by a code called DiffServ Code Point (DSCP). Different values of DSCP are defined for different services so that the IP router that forwards the IP packet containing a given service (e.g., email, web page, voice, or video) toward the destination gives a suitable priority to the incoming IP packet. For example, DSCP=0 means that the service is a delay-tolerant and the IP router could let this IP packet wait in the buffer for some time when it is busy with IP packets carrying other higher priority services. In contrast, DSCP=30 means that the IP packet is carrying a video streaming packet and hence warrants faster packet forwarding from the IP router.

As discussed in the paragraphs above, numerous and complex interactions among the mobile device, the radio network, the core network, the IMS network, and the PCC network are required so that the subscriber can access a variety of Internet access services. *Multiple services are offered to the consumer as a single integrated information service with the mobile device and the network working closely together and carrying out complex, intense, and custom processing*.