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**Cars, Broadband, Internet:
*And why the road to innovation may go
through Washington DC***

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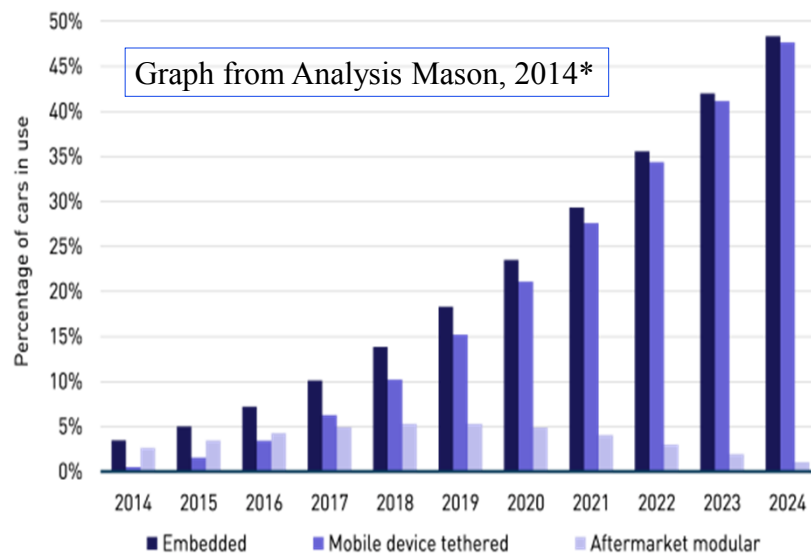
www.ece.cmu.edu/~peha/bio.html

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Car Infotainment

- Many applications and services can use communications from car
 - Entertainment
 - e.g. Pandora in-car app has over 2.5 million listeners
 - Mobile Internet access
 - Navigation, Location Based Services
 - Communications
- Estimated global market of \$14.4B in 2016
 - (According to Markets & Markets)

% Cars With Cellular (Global)



* analysismason.com/About-Us/News/Insight/connected-cars-Jun2014-RDME0/#09%20June%202014

Cellular Monopoly Inside?

- Cellular could emerge as basis of car infotainment systems
- But carrying traffic on a cellular macrocell is costly
- Easy to become dependent on a single cellular provider
 - Rely on ubiquitous coverage which few can offer
 - High switching cost

Vehicular Networks

- Mesh network consisting of
 - Vehicle to vehicle connections (V2V)
 - Vehicle to roadside infrastructure connections (V2I)

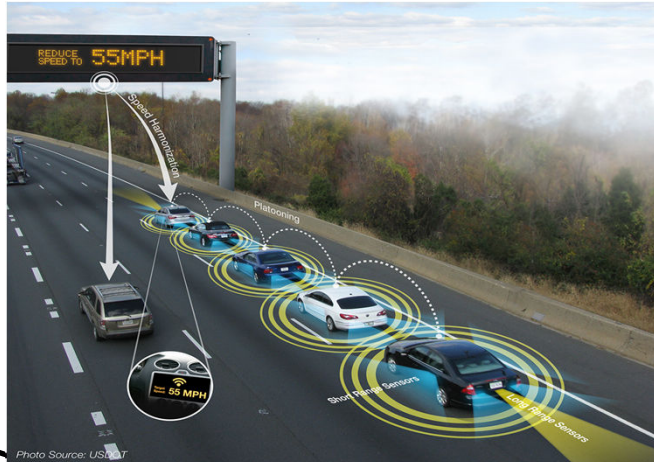


Figure from
U.S. Dept. of
Transportation

Vehicular Networks

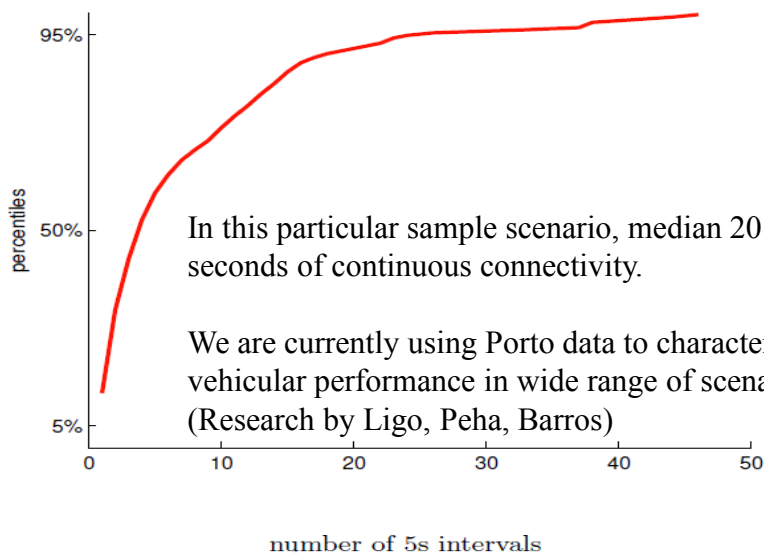
- Many car companies have ongoing research projects in Europe and U.S.
- U.S. Dept. of Transportation may require new cars to support vehicular communications for safety applications
 - Accident avoidance, intersection notification, emergency alerts, vehicle diagnostics & inspection
- Can be used for non-safety applications as well
- But is QoS good for all applications?
 - Sometimes connectivity is lost
 - Data rate varies with signal strength, congestion
 - We are currently doing research to answer this question

Deployment in Porto, Portugal



- 600 buses & taxis provide free Wi-Fi to passengers
- Passengers connect to the Internet with smartphones, tablets and laptops
- 70,000 users, 3 TB traffic per month
- Carnegie Mellon is working with University of Porto, Veniam'Works, others

V2X Connectivity Can Be Intermittent



The Multi-Connected Car

- Car router that can connect to multiple networks
 - *Multiple* cellular nets, vehicular net, Roadside wi-fi
- Networks differ in price, availability, QoS
 - Best choice changes as location changes
 - e.g. distance to closest transmitter
 - Best choice changes over time
 - Congestion, “peak hour” pricing
 - Best choice depends on application
 - Different QoS requirements, willingness to pay
- CMU is developing protocols that dynamically assign *each traffic flow* to the network that currently meets needs best (Research by Zhang, Peha, Sirbu)

Will Dynamic Switching Happen?

- Great advantages if this is supported
 - End user always gets service that best meets needs
 - More efficient use of network resources, lower costs
 - Use the network that can provide the service using very little of the scarce and costly resources
 - e.g. a tower 200 meters away can offer a given data rate with far less spectrum than a tower 400 meters away.
- We are working on overcoming the technical obstacles, but is that enough?
 - Business practices matter
 - Regulation matters

The View From A Dominant Carrier

- If it is easy to switch providers, competition is likely to intensify
- Pressure to decrease prices
 - Its OK to charge more than a competitor, as long as price difference < switching cost
- Fewer advantages to being big
 - When switching is easy, a carrier can succeed by serving a small area well, and letting others serve everywhere else
- If a carrier doesn't want this, it won't allow customers to use devices that can multi-home

Reprogrammable SIM cards

- New Apple iPads have SIM cards that are reprogrammable ("Apple SIM")
 - Not multihomed, but lower switching costs than normal SIM
 - As of Jan. 6, 2015, also the iPhone 6
- Not widely embraced so far
 - Verizon does not allow reprogrammable SIMs
 - AT&T allows but locks to AT&T, so card must be replaced if customer wants to use a competitor
 - Only EE supports in Europe (U.K.)
- *Should a carrier have the right to prohibit use of certain devices on its network?*

This is Net Neutrality

- Definitions differ greatly.
 - Undermining the “debate”
- According to initial principles endorsed by the FCC in 2004, consumers should
 1. have access to legal content of their choice
 2. be able to run applications of their choice
 3. be permitted to attach devices of their choice
 4. receive meaningful information on their service plans

Current Status

- The FCC is likely to vote on new net neutrality rules on Feb. 26, 2015
- There are significant risks
 - If the FCC does too little
 - If the FCC does too much
- The issue is hotly debated by many, and understood by few

Access and Discrimination

- Access to content/application/device could depend on
 - availability
 - availability at acceptable quality of service
 - availability at a reasonable price
- Should discrimination in these three areas be regulated?
 - Blocking
 - quality of service
 - pricing
- In general, net neutrality advocates want to limit discrimination.
- In general, net neutrality opponents want to protect discrimination.

Allowing Discrimination Can Be Good

- Blocking
 - Malware (application), Spam (content), transmitters that cause excessive interference (device)
- Discrimination to adjust QoS
 - To support applications that benefit from QoS protection
 - To enhance fairness, e.g. lower priority of heavy users relative to light users
- Discrimination in pricing
 - Differential QoS usually requires differential pricing

Allowing Discrimination Can Be Bad

- “Innovation by permission”
 - If ISPs discriminate by content/application/device, then new content/app/device may need to negotiate with ISP to avoid blocking or poor QoS
 - e.g. car router that can multi-home
- ISPs may protect legacy services & affiliates
 - Better QoS is possible for ISP than for competitors
 - Less choice for users, higher prices.
 - Today VOIP or video streaming. Tomorrow ... ?
 - Works if competition among ISPs is weak

Rents on Competitive Markets

- Instead of charging by month or by GB, separate traffic by type of use (application & content)
- Charge for carrying traffic associated with each type of use whatever the market will bear
 - Two-way video for medicine vs entertainment
 - Video streaming of movies vs MOOCs
- ISPs with significant market power can charge oligopoly rents on given type of use even when there are many competing providers

My Proposal

- Unreasonable discrimination is prohibited.
Reasonable discrimination is allowed.
 - IAPs can offer services with different QoS and pricing
 - To be reasonable, if an IAP offers superior QoS to one user, the IAP must offer the service to all similarly situated users at same terms and conditions

Issues To Watch

- Will present the five biggest and most controversial decisions the FCC will make
 - And relevance to innovation

Big Issue 1: Under What Legal Authority?

- When 1996 Telecom Act was written, authors were not thinking of Internet.
- Courts say Internet is covered, but under which rules?
 - Rules for a “Telecommunications Service”? (Title II)
 - Rules for “Advanced Telecommunications”? (Section 706)
- Title II would give FCC more authority, but FCC does not have to use it
- Contrary to what some say, no one is even considering regulating Internet “like a utility”
- No direct impact on innovation. Possibly indirect impact

Big Issue 2: Is “Pay for Priority” Allowed?

- Can an Internet access provider (IAP) offer better QoS for one class of traffic vs. another?
- If yes, can an IAP charge for better QoS?
- If yes, who can an IAP charge?
 - A direct customer?
 - The content or application service provider who is communicating with the customer? (PAY FOR PRIORITY)
- Bad rules could
 - Allow IAPs to hinder development of innovative applications & services by blocking, discriminating, charging rents.
 - Prohibit IAP from providing QoS needed for innovative applications & services

Big Issue 3: Wired vs. Wireless

- 2010 Rules were different for wired and wireless
 - Unlike wired IAPs, wireless IAPs were free to block most applications, content, and devices
 - except web traffic and apps that compete with telephony
 - Unlike wired IAPs, wireless IAPs were allowed to use “unreasonable discrimination”
- Roughly 75% of adults in U.S. now have a smart phone
- Impact on innovation
 - Could bring the same benefit/harm to services delivered over wireless

Big Issues 4: “Managed/Specialized Services”?

- *Managed/specialized services* may use TCP/IP but are managed separately from public Internet service.
 - Comcast Digital Phone uses a logically separate IP channel to carry its VoIP traffic over its cable modem service
 - This channel has QoS and is not available to Vonage
- Some believe they should be exempt from rules.
- 2010 Rules raised but did not answer this question
- Impact on innovation
 - If anything can be an managed/specialized service, this could be a massive loophole making many rules irrelevant.

Big Issue 5: What about interconnection?

- 2010 Rules addressed what an IAP could do within its network.
- Largely ignored interconnection agreements
- After several big public disputes, some want to add rules on interconnection.
- Could affect deals between IAPs and backbone networks, CDNs, and very large content/application service providers
- Effect on innovation
 - TBD. Largest effect on content & application service providers that run their own networks

Summary

- Vehicular networks have great promise
 - A new wireless infrastructure that can bring wireless broadband to much of a city at little cost
 - QoS issues may make it excellent complement to cellular rather than complete substitute
 - Benefits of the multi-homed mobile user
- Upcoming net neutrality decision has enormous implications
 - If it goes too far, could inhibit applications that benefit from superior QoS
 - If does not go far enough, could give ISPs with market power incentive & ability to charge rents, undermine competition
 - The devil is in the (poorly understood) details

Biggest Issues to Watch

- Source of legal authority
 - Title II vs Section 706
- Pay for Priority
- Wired vs wireless
- Managed/specialized services
- Interconnection



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