

# Network Protocols and Economics

Jean Walrand  
U.C. Berkeley

Joint work with NetEcon group at UCB (Venkat Anantharam, Shyam Parekh, Galina Schwartz, Libin Jiang, Nikhil Shetty, Mark Felegyhazi, Assane Gueye, Jiwoong Lee, Pravin Varaiya), John Musacchio, Rahul Jain, and Linhai He.

NEGT - USC - 10/02/2009

# Goal

- ✦ Explore how **economics** should influence the design of network protocols

Talk focuses on high-level questions, not on specific models or analytical results.

# Outline

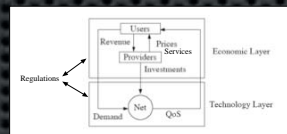
- ✦ Protocols
- ✦ Big Picture
- ✦ Neutrality
- ✦ Service Differentiation
- ✦ User Discrimination
- ✦ Economics of Neutrality
- ✦ Economics of Services
- ✦ Economics of Security
- ✦ Conclusions

# Protocols

- ✦ Access control (e.g., cellular, WiFi, LTE, P2P, Cloud, VPN)
- ✦ Traffic control (e.g., TCP, UDP, LTE, DiffServ, ...)
- ✦ Service choice (e.g., LTE, Overlay Routing)
- ✦ QoS visibility (e.g., trace route, ping)
- ✦ Usage visibility (e.g., NetFlow)

Thus, instead of focusing on “internal” protocols and the possible impact of their manipulation by strategic users, we focus on the protocols seen by “normal” users.

# Big Picture

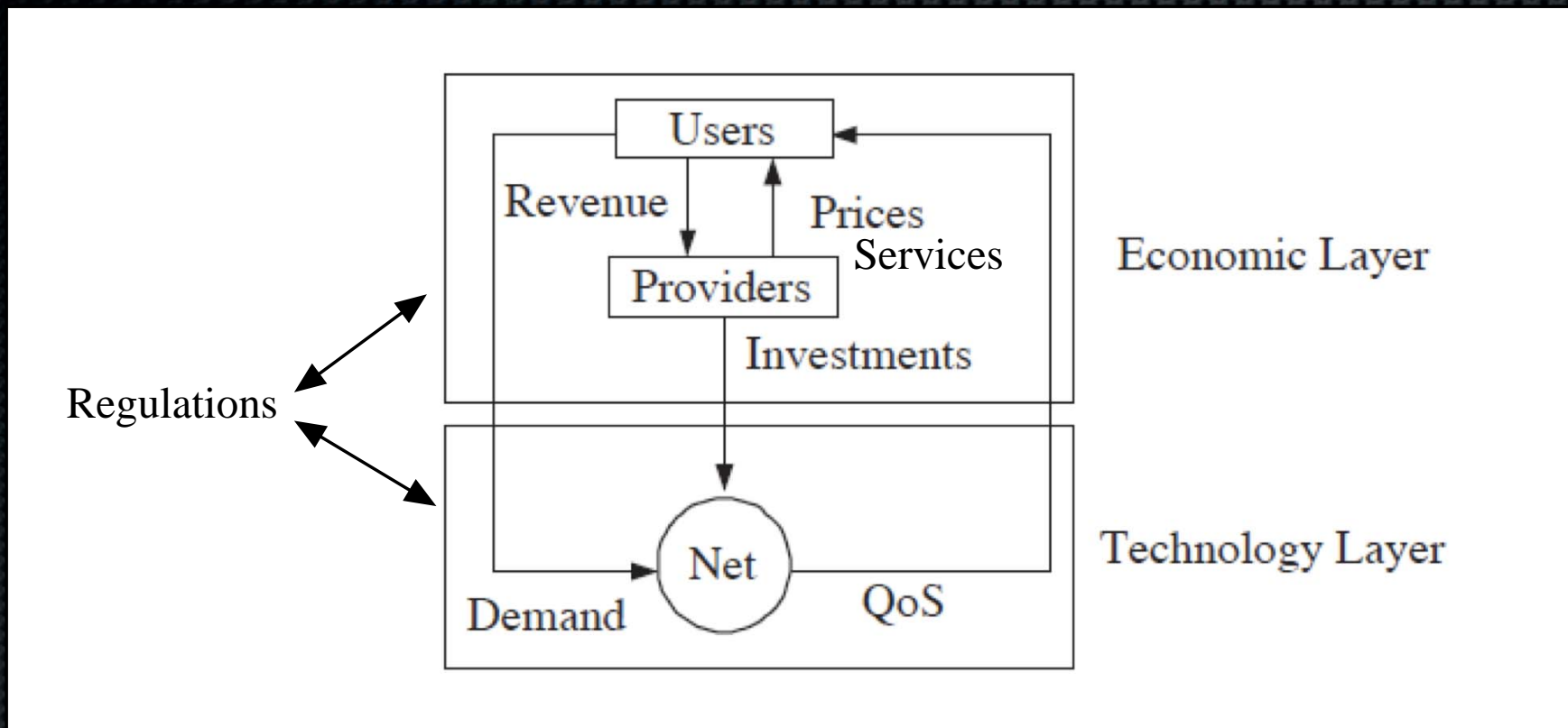


Protocols affect the technology layer and the interface between the two layers.

They modify the equilibria of the closed-loop system.

Tension between regulations, efficiency, and fairness.

# Big Picture



Protocols affect the technology layer and the interface between the two layers.

They modify the equilibria of the closed-loop system.

**Tension between regulations, efficiency, and fairness.**

# Neutrality

- *1) open content* - every user can access any legal content
- *2) open applications* - user can run any application that does not harm the network
- *3) open devices* - can connect any device that would not harm the network
- *4) open services* - every user get information about service plan

*[Michael Powell, FCC chairman, 2004]*

# Neutrality

- *5) non-discrimination*—broadband providers cannot discriminate against particular Internet *content* or *applications*.
- *6) transparency*—providers of broadband Internet access must be transparent about their network management practices.

*[Julius Genachowski, FCC chairman, 9/21/2009]*



# Service Differentiation

- Example 1: Residential DSL (AT&T, 9/2009)

	Elite	Pro	Express	Basic
Down	6M	3M	1.5M	768k
Up	768k	512k	384k	384k
\$/mo	35	30	25	20

Thus, many services are possible. The choice is made by users, not by the provider. You are allowed to get more for a higher price.

# Service Differentiation

- Example 2: **Hypothetical Dynamic DSL**
  - Dynamically switch between Elite and Basic
- Price: prorated to usage  
(e.g., Basic during day, Elite 1 hour evening: \$25/mo)

User chooses service. Enables congestion pricing and service differentiation.

# Service Differentiation

- Example 3: **Hypothetical Services**
  - NG: Very low delay, rate 1 packet/sec., burst 20 packets/sec.
  - RT: Low delay, rate 64kbps
  - FT: rate up to 6Mbps/768kbps

**User (not network) decides which applications use what service**

# Service Differentiation

- Example 4: **Overlay Routing**
- Subscribers get “enhanced routing” based on network congestion.

Example 5: **Service Class in LTE or WiMAX**

- Choice of guaranteed rate service or best effort

**Again: user choice.**

# User Discrimination

- Example 1: **VPN**
  - Users pays special tariff for that service (which may share resources with other services charged differently)
- Example 2: **800-number**
  - Content provider pays for delivery, not end-user
- Example 3: **Reversed-charges**
  - Called party pays for connection
- Example 4: **Privileged Access**
  - Users with “secured device” get faster access to server

**User discrimination may be beneficial.**

# Economics of Neutrality

## 1. User Discrimination

- Question:  
Should ISPs be allowed to charge content providers?
- Answer: Might be beneficial for ISPs and content providers ...
- Justification: If improved revenues bring higher investment, possibly all users will gain ...
- Legal? Is this discrimination based on content?
- Can this mechanism be implemented as a service choice?

# Economics of Neutrality

## 2. Service Differentiation

- ✦ Fact:
  - Service differentiation implies pricing
  - Open access does not mean same service for all
- ✦ Examples:
  - ✦ LTE, WiMAX
  - ✦ Network Virtualization (e.g., GENI)

# Economics of Neutrality

## 2. Service Differentiation

- ❖ Question:  
What is the down side of offering different services? How to mitigate it?
- ❖ Answer: Some users might lose out.
- ❖ Justification: Low-quality service is now worse and some users need to pay for the high-quality service to get back what they had before.
- ❖ Remedy: Fractional neutrality ...: limits user suffering; If ISP re-invest extra profits, all users may gain



# Economics of Services

## 1. Improving Social Welfare

- Fact:  
Heavy users clog network (10% use 90%)
- Possible Remedies:
  - Congestion Pricing: Poorly accepted by users
  - Time-of-day pricing: Still variable bill
  - High-Quality tokens: consumed faster when congested

The challenge is to find mechanisms for charging externality without deteriorating the openness.

# Economics of Services

## 2. Incentive for Better Services

- ✦ Fact:  
Users do not know which network provider is bottleneck
- ✦ Possible Remedy:
  - ✦ Provide visibility (a la traceroute)
  - ✦ Provide choice (e.g., overlay routing)
  - ✦ This drives traffic to better service --> correct incentives

The challenge is to offer mechanisms that provide the correct incentives to network providers: higher reward for better service.

# Economics of Security

- Fact:  
Users do not care enough about the positive externality of their investment in security [=> Under-investment]
- Possible Remedies:
  - Insurance and liability: Liability too difficult to assess; moral hazard reduces network security
  - Mandatory certification (vaccination, smog test)
  - Better service if certified (Prius in car-pool lane)

# Conclusions

- ✦ Internet success comes largely from its openness
- ✦ Two aspects: Free Speech & Performance
- ✦ “Network cannot pick winners”
- ✦ Rules for preserving this openness are necessary
- ✦ However, there is a tension between efficiency and regulations
- ✦ Important class of problems: effect of rules on efficiency

# Conclusions

- Efficiency would require charging for externality; this may conflict with non-discrimination principles.
  - Services (visibility and choice; tokens for high-quality)
  - Security certification (mandatory or incentive)
  - Should ISPs be allowed to charge for P2P traffic from content providers?
- Competitive advantage of better network technology may conflict with the transparency principle
- The rules of the game are being defined now, without us ....

# References

- Julius Genachowski, "Preserving a Free and Open Internet: A Platform for Innovation, Opportunity, and Prosperity," Brookings Institution, 9/21/2009.
- Jean Walrand: Economic Models of Communication Networks, Sigmetrics Tutorial, 2008. Chapter 3 in Performance Modeling and Engineering. Liu, Z., Xia, C., Liu, Z., and Xia, C. (Eds), Springer Publishing Company, 2008.
- J. Musacchio, G. Schwartz and J. Walrand, "A Two-Sided Market Analysis of Provider Investment Incentives With an Application to the Net-Neutrality Issue," to appear in Review of Network Economics, 2009.
- G. Schwartz, N. Shetty and J. Walrand, "Impact of QoS on Internet User Welfare," WINE 2008.
- L. Jiang, V. Anantharam and J. Walrand, "Efficiency of Selfish Investments in Network Security," NetEcon'08.
- G. Schwartz, N. Shetty, J. Walrand. Impact of QoS on Internet User Welfare. NOMS 2008.