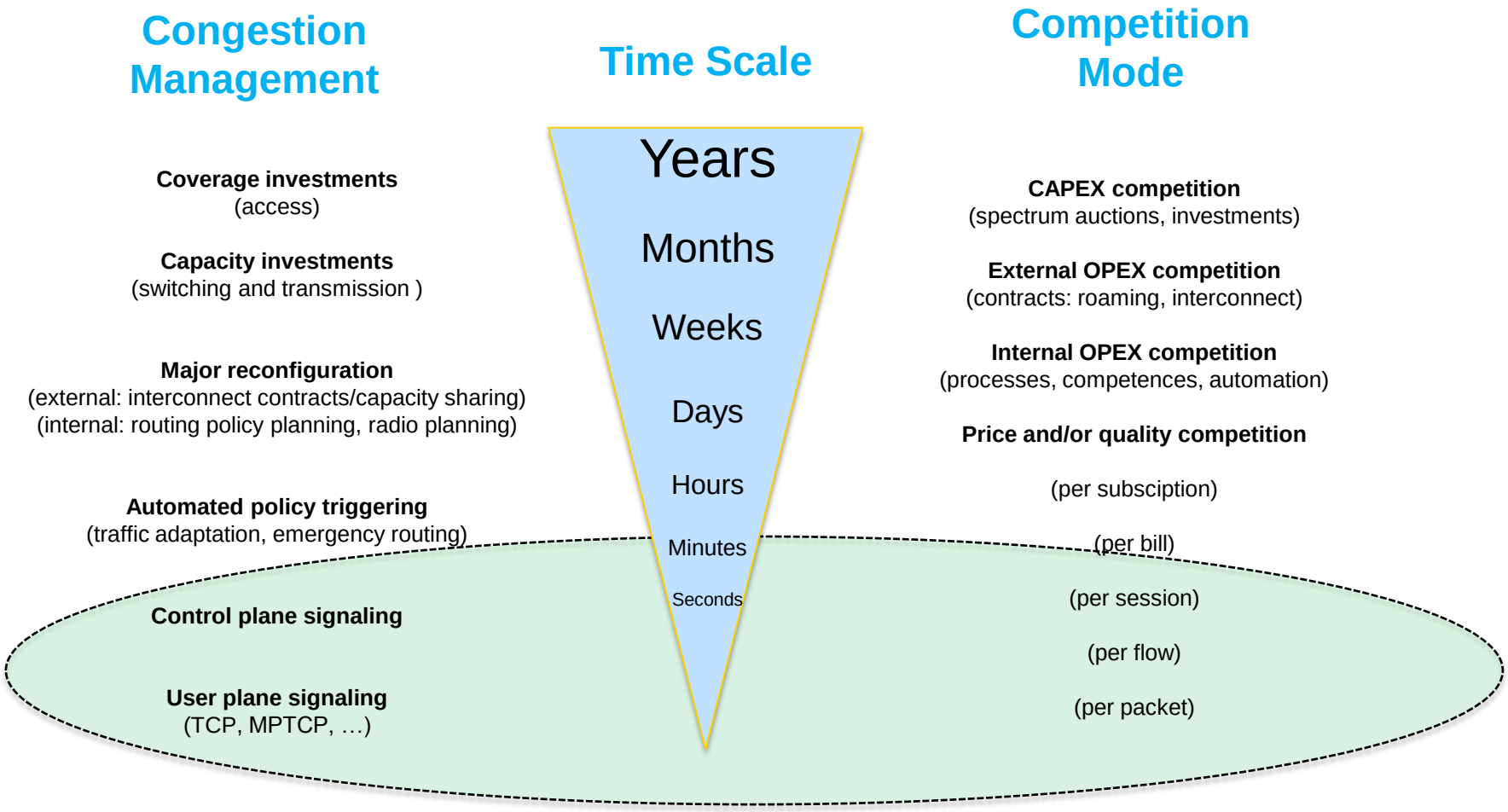
Aalto University
School of Electrical
Engineering

Congestion Management Strategies and Mobile Access Competition

Heikki Hämmäinen
Aalto University

2nd Workshop on Internet Economics
UCSD, San Diego, Dec 1-2, 2011

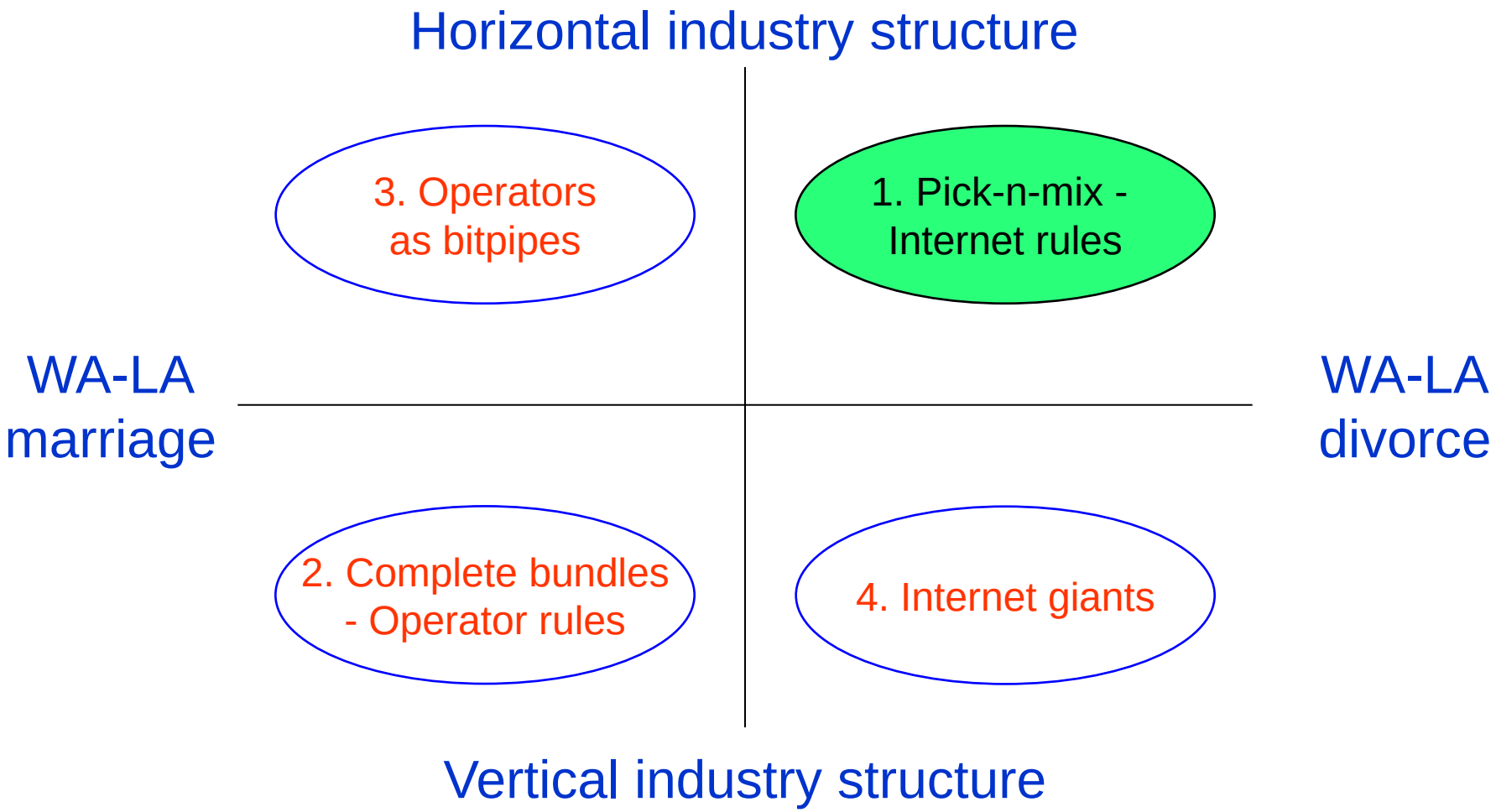
Time Scales of Congestion and Competition



More competition implies shorter time scales, and vice versa

Wireless Access Scenarios

Wide Area (WA) vs Local Area (LA)

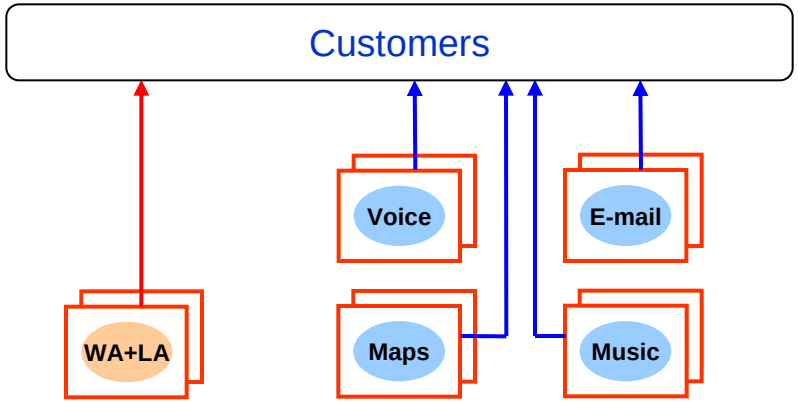


Source: Smura et al, 2009

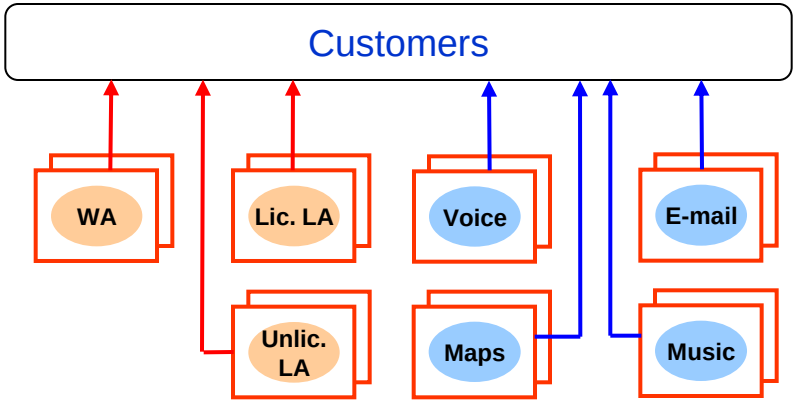
Scenarios as Industry Structures

Horizontal industry structure

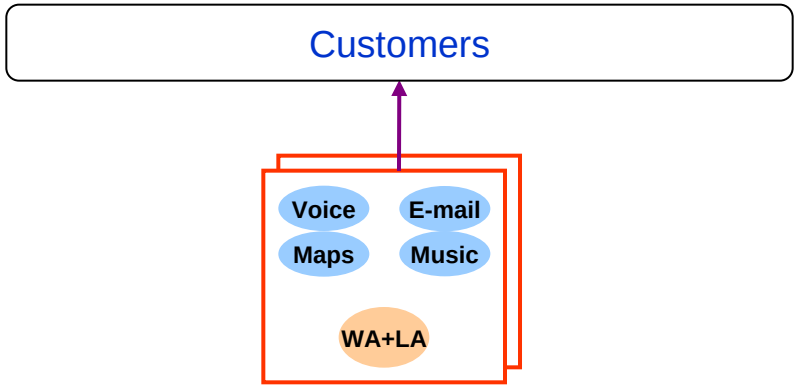
Scenario 3: Operators as bitpipes



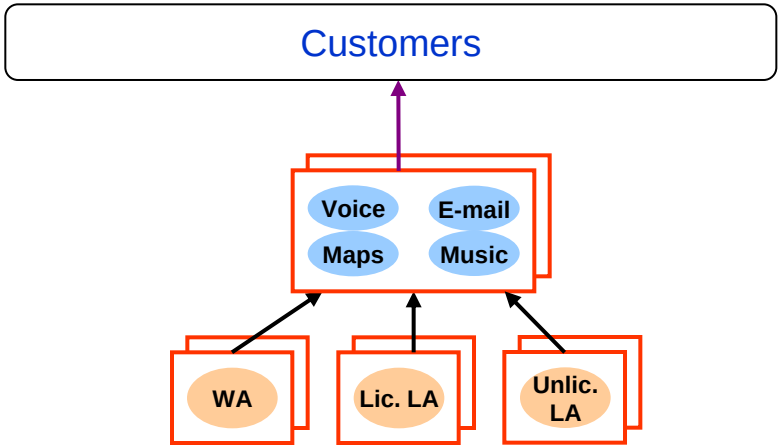
Scenario 1: Pick-n-mix



Scenario 2: Complete bundles



Scenario 4: Internet giants



WA-LA marriage

WA-LA divorce

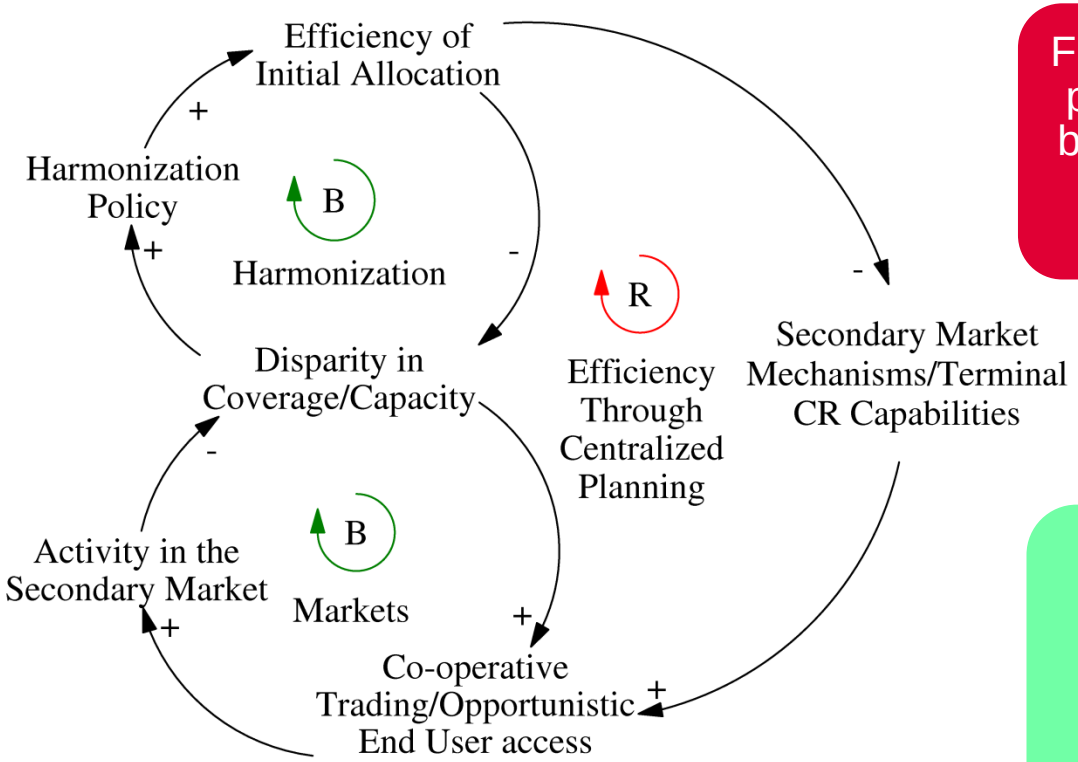
Vertical industry structure

Emerging and Advanced Markets: Case India vs. Finland

	India	Finland
Landlines/100 people	3.1	26.9
Broadband Internet subscribers/100 people	0.6	28.8
Internet users/100 people	5.1	82.5
Mobile subscriptions/100 people	43.8	144.6
Harmonization Policy of the Government	GSM in 900/ 1800; CDMA in 800; WCDMA in 2100; BWA in 2300 MHz; No unified view	GSM, WCDMA and LTE adopted in harmonized spectrum blocks as per EU directives
Average spectrum allocation per operator per License Service Area	2 × 7 MHz in 900 2 × 7 MHz in 1800 2 × 5 MHz in 2100	2 × 11.3 MHz in 900 2 × 24.8 MHz in 1800 2 × 15 MHz in 2100

Source: Sridhar et al, 2011

Advanced and Emerging Markets on Separate Paths?



Finland: harmonization policy path → demand met mostly by centrally planned efficient initial allocation (spectrum refarming, digital dividend)

India: market based policy path → demand met increasingly by end-user choice (multi-SIM phones) and secondary markets (national roaming)

Source: Sridhar et al, 2011

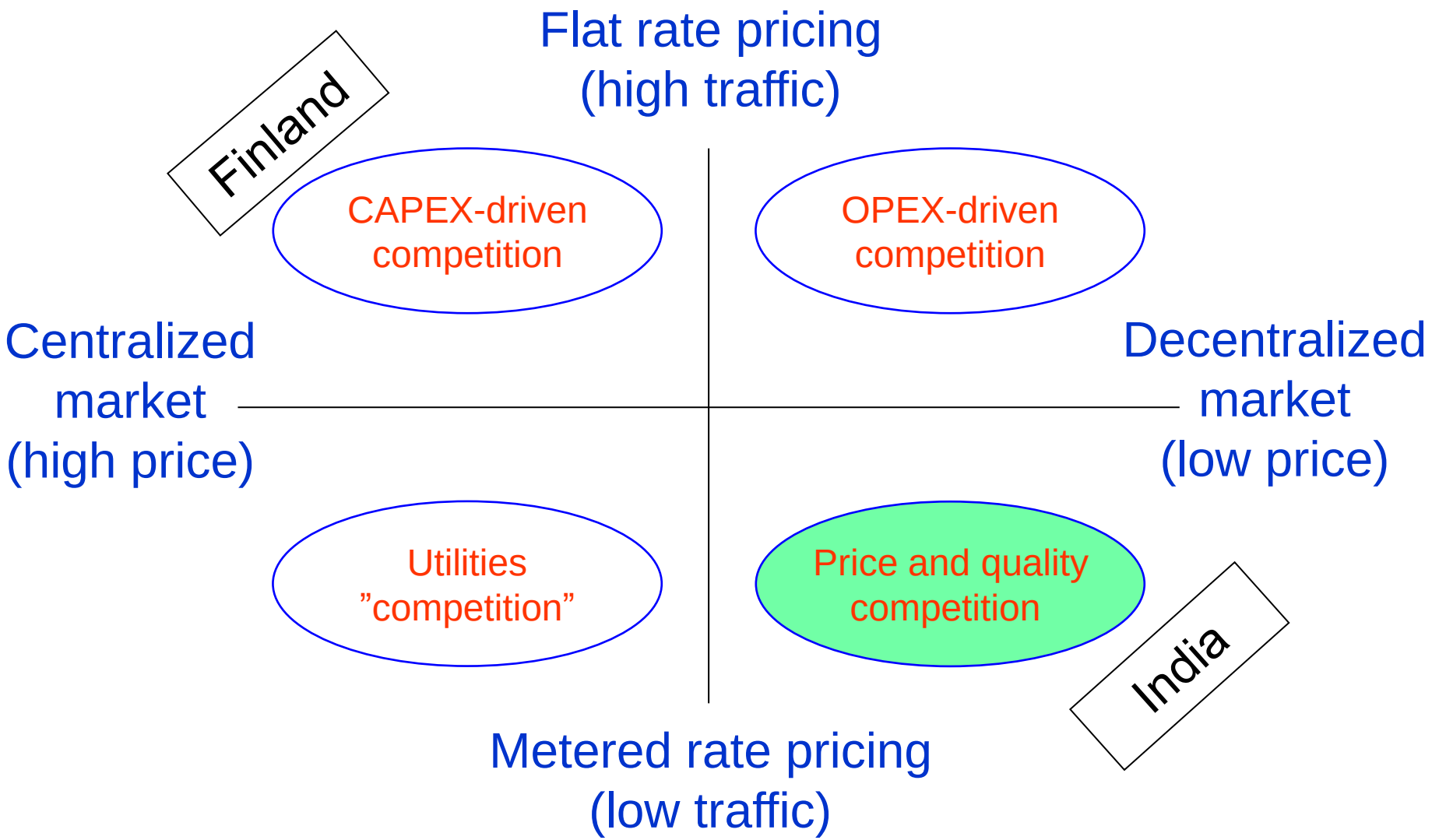
Towards More End-user Choice: Multi-SIM Phones

- In India subscribers use Dual-SIM phones to optimize usage based on
  - Tariff plans and roaming charges of different operators
  - Operator's network load → if subscriber finds network operator busy, can switch the SIM
- Resembles closely the decentralized Cognitive Radio (CR) paradigm
  - Either subscriber uses his/her cognition to switch across networks, or
  - Alternatively an intelligent device executes policies defined by end-user depending upon usage pattern, coverage and capacity of networks
- Differs from advanced markets where users are not that worried about optimizing usage
  - Subscription with only one operator
  - Operators typically offer flat rate pricing schemes
  - Operators perform traffic shaping and optimize the network resources

Currently about 15% of all 2G mobile phones in India are multi-SIM;
up to 40 percent of all new mobile handset in India are multi-SIM;
(even though they are about 20-25% more expensive than single-SIM handsets).

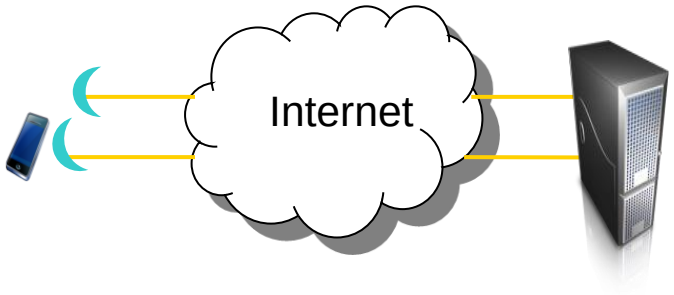
Source: Sridhar et al, 2011

Competition Scenarios for Widearea Wireless



Multipath Example: Multipath TCP

- **A manifestation of resource pooling principle which requires**
  - Operating system support
  - Multihoming capability



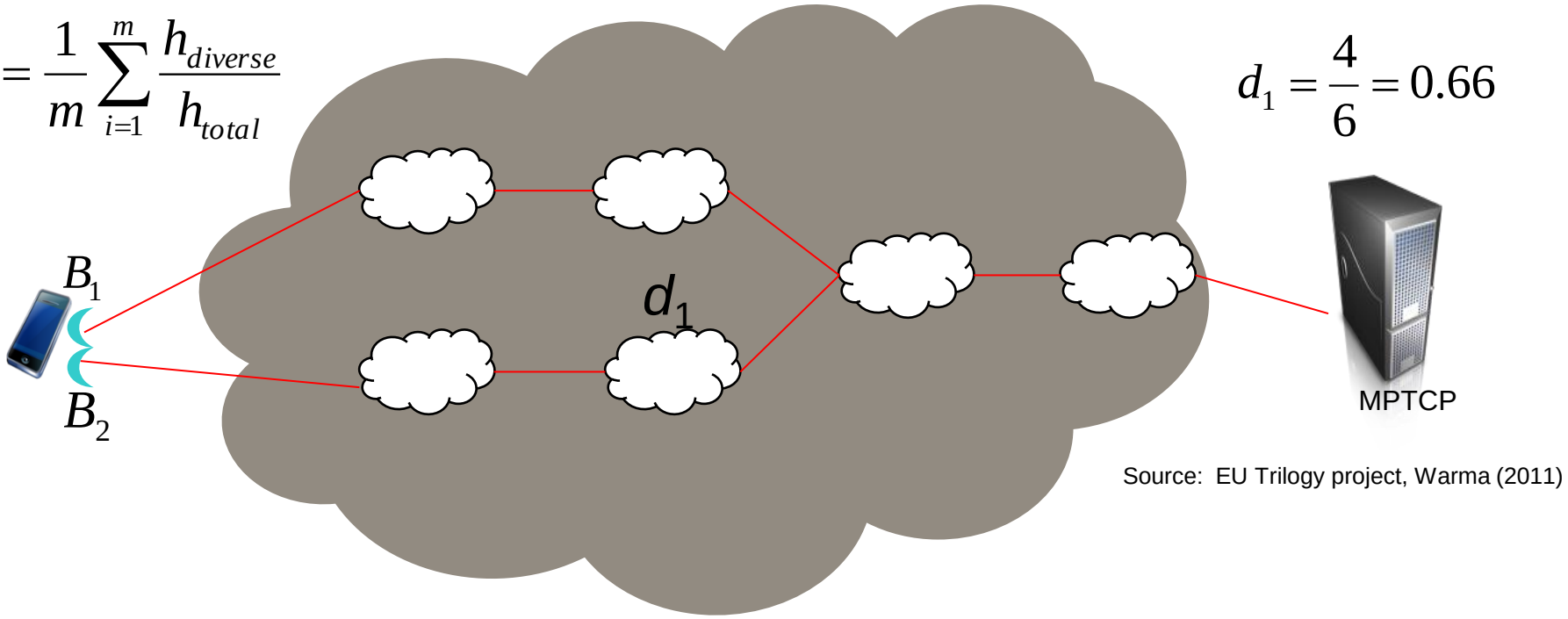
- **Multipath TCP should**
  - increase throughput and resilience
  - move traffic away from congested paths
  - enable seamless transition between access technologies, e.g. WLAN and 3G

Sounds good in theory but is there enough market demand for this protocol?

Multipath Case: MPTCP for Mobile Access

$$d = \frac{1}{m}\sum_{i=1}^{m}\frac{h_{diverse}}{h_{total}}$$

$$d_1 = \frac{4}{6} = 0.66$$



Source: EU Trilogy project, Warma (2011)

- Natural path diversity ***d*** of Internet evolves over time via updates in topology, interconnect agreements, and routing tables (note that path diversity can be defined in multiple ways)

- Path diversity is the basis of multipath benefits (which can be intentionally influenced: e.g. MPTCP blocking, source routing, BGP multipath extensions)

- Adoption of multipath communications would increase the capacity utilization of Internet by an increment (and users benefit indirectly via investment savings and competition)

How does Multipath Affect Wireless Competition?

Possible steps toward multipath wireless communications

1. User selects the operator&access (per session competition)
   a) Between MNOs (using dual-SIM, e.g. India)
   b) Between MNO and WiFi (using a multiradio device, e.g. Finland)
2. User runs multipath on apps level (per flow competition)
3. User runs multipath flows, e.g. MPTCP (per packet competition)

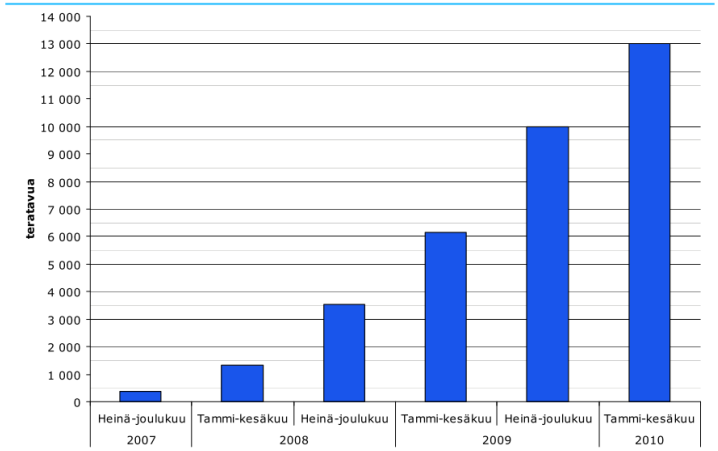
• High competition between widearea operators (e.g. India) or wide vs. local (e.g. Finland) enables these steps

• Multipath increases competition by enabling real-time comparison of price and quality

• The most intense per packet competition takes place when multipath runs over metered rate pricing

Towards More Flexible Usage of Spectrum

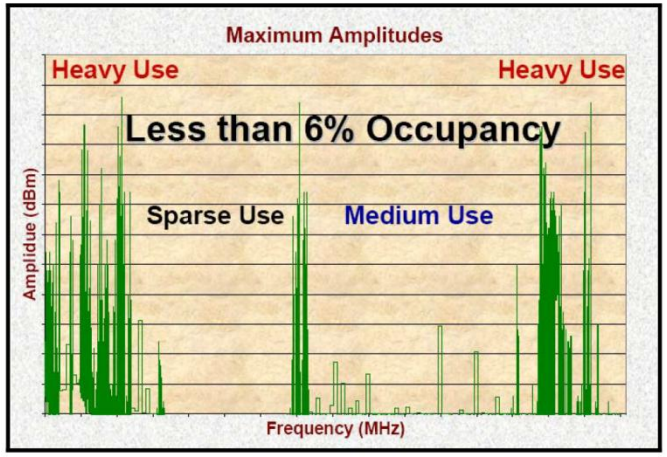
Data volume transferred over mobile networks in Finland 2007-2010



Kuvio 8: Matkaviestinverkoissa siirretyn dataliikenteen määrä 2007 - 2010.

Source: Ficora, Casey (2011)

Mobile and wireless data usage showing exponential growth



Source: Janka&Dorfman, 2005.

Spectrum is not utilized efficiently by the licensees at the moment

Cognitive radio techniques could be used to dynamically utilize spectrum more efficiently

1. Secondary (cognitive) users can opportunistically access spectrum “whitespaces” when primary users not using it
2. Co-operative trading, leasing and auctioning of Frequency-Space-Time (FST) blocks between secondary users and spectrum rights owners

How do Multipath (e.g. MPTCP) and Cognitive Radio (CR) Depend on Each Other?

- Assumptions
  - MPTCP covers the end-to-end flow, CR only the wireless hop
  - Identifying the congested link/router is challenging
  - MPTCP only senses the congestion of end-to-end paths
  - Mobility management tunneling (e.g. LTE) hides radio congestion from IETF
  - 3GPP needs to handle the congestion on both sides of a base station

- Solution alternatives
  - MPTCP and CR run independently (CR only adds more dynamics in radio)
  - MPTCP kicks CR as necessary (inside the mobile host)

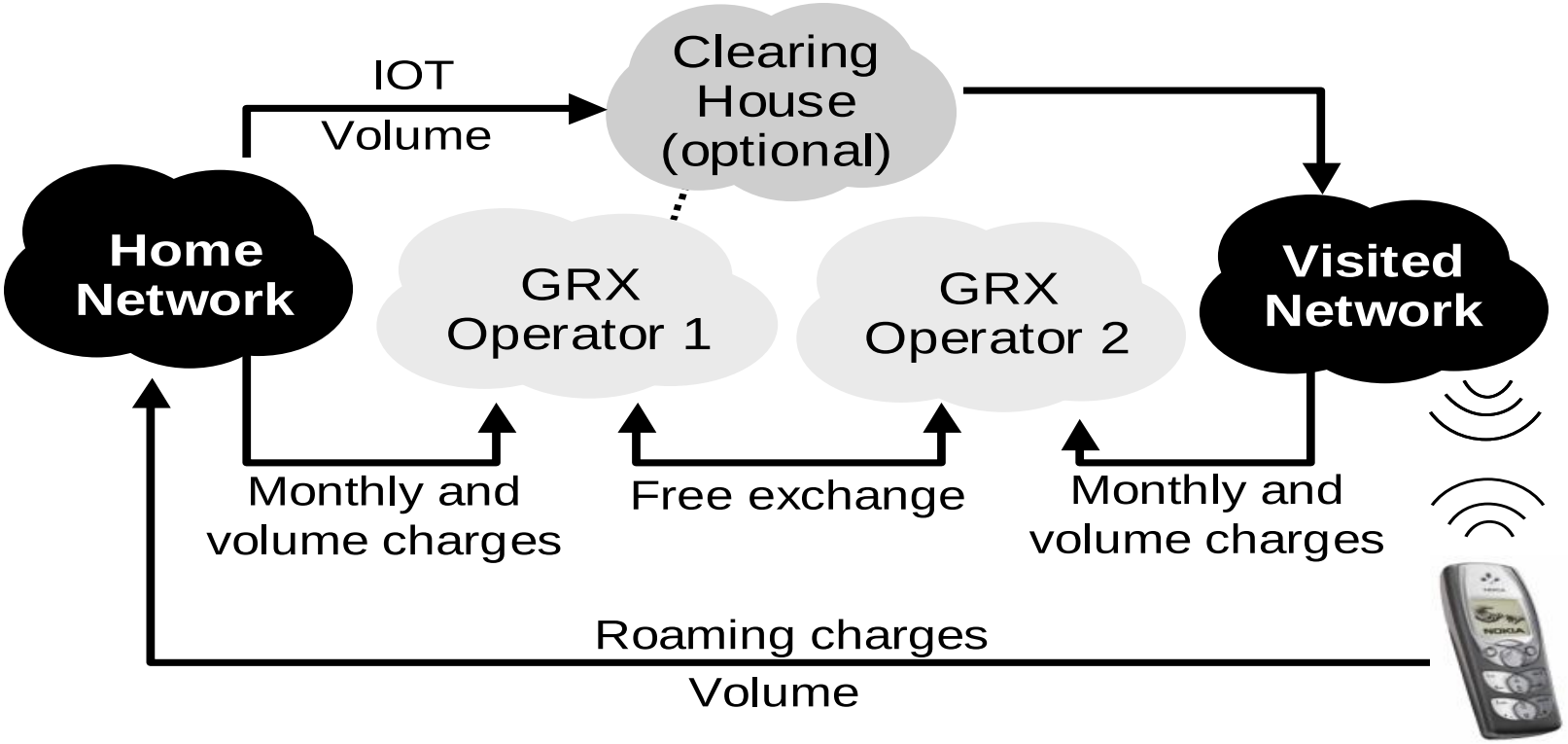
- It appears that the access impact on interconnect goes via MPTCP (we can ignore CR in this MPTCP+CR scenario)

Impact of Mobile Access Evolution on Interconnection?

- Relative share of wireless device traffic increasing also in interconnection
- Role of Internet peering vs. private mobile peering (3GPP/LTE)?
- Higher access competition affects indirectly the interconnect pricing
- Specific multipath (MPTCP) impact:
  - Multipath breaks the traditional single path end-to-end value chain
  - Multipath makes strict (flow-based) QoS control difficult
  - Path diversity battle (diversity up or down)

GPRS Roaming

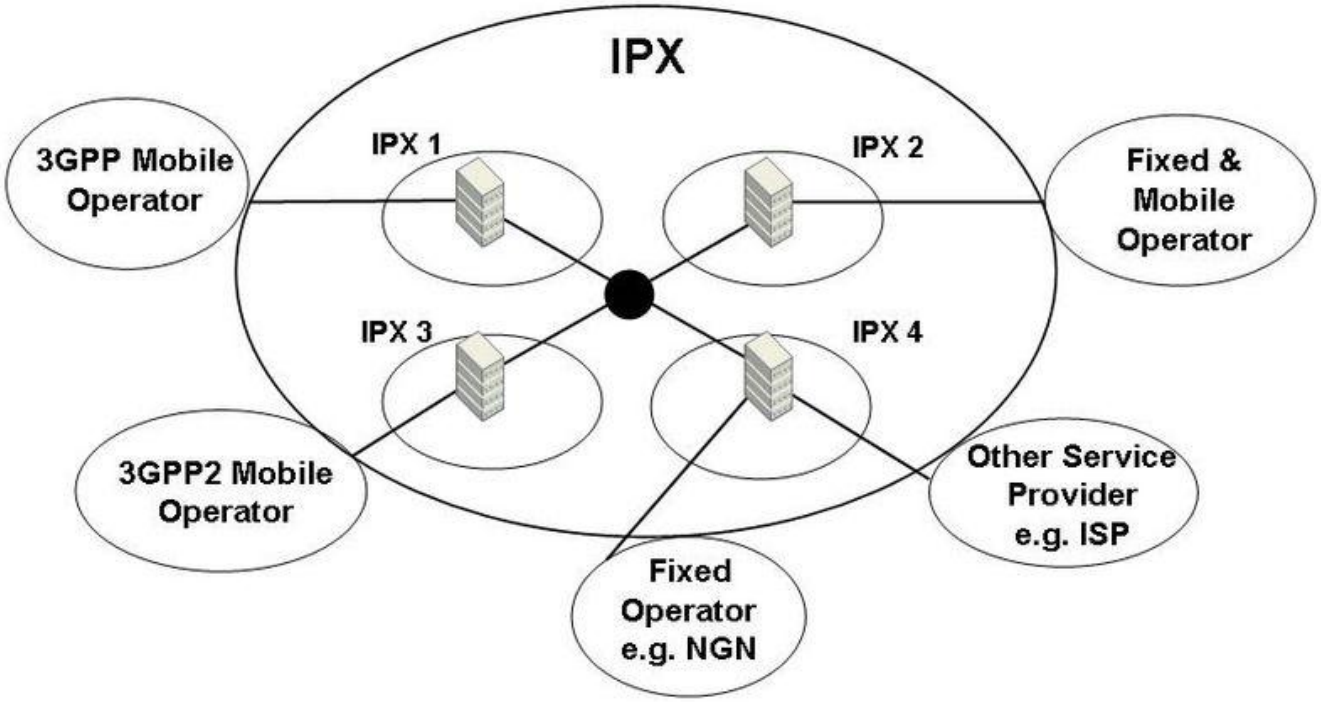
Business Interfaces between Players



- Bilateral roaming agreements between GPRS operators
- Settlement of inter-operator tariffs (IOT) via clearing houses
- Transport agreements via GPRS Roaming eXchange (GRX) operators

IPX (IP eXchange)

GRX evolution to support QoS charging for e.g. IMS



- IPX is all-IP which enables interoperability with non-3GPP systems
- Still based on a private IP backbone (for QoS/DiffServ)
- Mobile operators face choices of interconnection
  - expensive QoS (IPX) vs. low cost best effort (Internet)
  - competition with Internet vs. Internet compliance

Possible Research Topics for Internet Economics

How to increase access competition in Internet?
E.g. analysis of individual protocols having potentially significant impacts (MPTCP?)

Evolution of Internet (IETF) vs. mobile (3GPP)?
E.g. analysis of interconnection, peering and roaming solutions

Evolution of IP layer vs. winning link layer (Ethernet, LTE)?
E.g. analysis of mobility management on different layers

Evolution of content delivery architectures?
E.g. analysis of access ISP vs. CDN provider, and national vs. foreign interests

Thanks!

Heikki Hämmäinen

Aalto University
Department of Communications and Networking

http://comnet.aalto.fi/en/research/network_economics
heikki.hammainen@aalto.fi