Forecasting (Ultra) Broadband and Other Information Technologies

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The Mysteries of (Ultra)Broadband
(Overcoming barriers to the diffusion of ultrabroadband communications)

- Bees and (Ultra) Broadband
- Too much BB
- Not enough BB
- Is 1 Gbps a MUST?

The Boston Globe
(March 12, 2007)
“Not so fast, broadband providers tell big users”!
“Firms impose limits even as demand rises”!
Ultra broadband overemphasized?

- "Broadband penetration should not be a goal in itself, given that it is uncertain to what extent consumers wish to have fast (ultra) broadband connections... ", Bijl and Peitz (2006), "Broadband access in Europe: Challenges for Policy and Regulation"
HEADLINES: the Impact of ultra broadband

- Ultra broadband will increase GDP by £22bn in 2015
- Currently 1.25 billion broadband users worldwide
- As more users are connected, so productivity improves
- Improvements in productivity have wider economic benefits
- The estimated impact of ultra broadband is similar to that of electricity
Hubs of digital technology innovation worldwide

Source: Hillner (2000) and UNDP (2001)
Correlation between broadband penetration and GDP growth (I)

Source: OECD
### Correlation between broadband penetration and GDP growth (II): Empirical Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td><strong>Micro Studies</strong></td>
<td></td>
</tr>
<tr>
<td>Forman et al. (2005)</td>
<td>Firms integrating the IT have the highest payoffs in terms of productivity increase.</td>
</tr>
<tr>
<td>Lehr et al. (2006)</td>
<td>The economic impacts of broadband are both real and measurable.</td>
</tr>
<tr>
<td><strong>Macro Studies</strong></td>
<td></td>
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<tr>
<td>Gartner (2002) USA</td>
<td>An increase of broadband penetration from 30% to 50% would increase GDP by 10%.</td>
</tr>
<tr>
<td>Tasman (2004) Australia (Victoria)</td>
<td>The average contribution of broadband to Victoria’s GDP growth is estimated to be between 0.47% and 0.82% for the period 2004-2015.</td>
</tr>
</tbody>
</table>
Broadband Penetration Top World Economies

Source: OECD, 2007. ...among the top broadband nations
(Ultra) Broadband technologies

Fixed
- Hybrid Fiber Coax: Cable TV and Cable Modems
- Digital Subscriber Line (xDSL)
- Broadband Power Line (BPL)
- Fibre to the Home/Curb (FTTH)

Wireless
- Microwave links
- MMDS (Multichannel Multipoint Distribution Services)
- FSO (Free Space Optics)
- Wi-Fi (Wireless Fidelity)
- WiMax (Worldwide Interoperability for Microwave Access)
- Satellite
- 3G (3rd generation Mobile Network)
## Evolution of Networks: Ubiquitous Networking and the Future of Ultra Broadband and Mobile

### Traditional Network

- **Disparate Networks**
  - Disparate PSTN and IP networks
  - Emergence of VoIP

- **Major breakthrough**: Start of PVoIP communications

### Network Convergence

- **Ubiquitous networks**
  - Integration of voice and data Networks (wireline & wireless) using IP based multi-service networks

- **Major breakthrough**: Start of multi-service Broadband packet networks

### Convergence in communications

- **Ubiquity of Communication services**
  - Real time communication Based on SIP
  - Unified Messaging
  - Find me, Follow me Communication
  - Intelligent Terminals

- **Major breakthrough**: Introduction of IP Multi-Media Systems (IMS) to 3G/4G
  - IPv6 Communication

### Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2000</td>
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<tr>
<td>2002-04</td>
<td></td>
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<tr>
<td>2005-07</td>
<td></td>
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<tr>
<td>and next?</td>
<td></td>
</tr>
</tbody>
</table>
Evolution of Networks: Fix & Mobile Ultra Broadband

<table>
<thead>
<tr>
<th>Traditional Paradigm</th>
<th>Current trends</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mobile (voice)</strong></td>
<td><strong>Data &amp; Voice</strong> (Mobility with Network connectivity)</td>
</tr>
<tr>
<td><strong>Fixed data</strong></td>
<td><strong>WLAN</strong></td>
</tr>
<tr>
<td></td>
<td>o Personal mobility</td>
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<tr>
<td></td>
<td>o High data rate</td>
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<tr>
<td></td>
<td>o Incremental infrastructure</td>
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<td></td>
<td><strong>3G GSM/WCDMA</strong></td>
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<tr>
<td></td>
<td>o Full mobility</td>
</tr>
<tr>
<td></td>
<td>o Modest data rate</td>
</tr>
<tr>
<td></td>
<td>o Brand new infrastructure</td>
</tr>
</tbody>
</table>

- **WLAN**
  - Local Area - Hotspots
    - on campus
    - at home
  - Wide Area - on the road
Today’s Networks … Running out of Gas: Prospects of ultra broadband

**Today’s total average bandwidth consumption**
- standard video, voice, and data package consists of 1 HDTV IP video signal (8 Mb/s, MPEG-4),
- 1 SDTV IP video signal (2 Mb/s, MPEG-4),
- 1 phone line (64 kb/s), and high speed Internet (5 Mb/s)
- Total bandwidth consumption - 15 Mb/s

**Tomorrow’s total average bandwidth consumption**
- In 5 years, the standard video, voice, and data package is likely to consist of 1 Super HDTV IP video signal (32 Mb/s, MPEG-4),
- 1 HDTV IP video signal (8 Mb/s, MPEG-4),
- 1 phone line (64 kb/s), and high speed Internet (20 Mb/s)
- Total bandwidth consumption - 60 Mb/s

Current technological constraints (there are now system limitations due to various dispersion penalties) limit the full development of the market for ultra broadband.

Historically, dispersion of single-mode fibers in these systems has not been an issue due to the relatively low data rates and limited distance.

However, for optical Ethernet access, distances up to 20 km and extended temperature ranges are obstacles to be overcome.
Ultra Broadband demand & supply (II)

- Affordability and ubiquity are necessary for ultra broadband to grow (new developments on IEEE’s 802.3ah)
- With the new standards, subscribers will be able to get 1 Gbs bi-directional capacity to the central offices
- This Gigabit passive optical network (PON) system uses low-cost opto-electronics and standard single-mode fibers.
The last mile imbalance: the FTTH alternative

- All the future networking standards for home are headed toward speeds of over 100 Mbps
- Generally, the home networks are relatively fast (the fibre loop and fibre backhaul network)
- But if the last mile connecting them is slow, there’s imbalance.

Present and future

FTTP allows subscribers with demand of 1 Gbs bi-directional capacity to the central offices. This Gigabit passive optical network (PON) system uses low-cost opto-electronics and standard single-mode fibres.
## Price comparison by country

<table>
<thead>
<tr>
<th>Country</th>
<th>Cost in US$ (Prices per 100kbps, as of July 2003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>0.09</td>
</tr>
<tr>
<td>Korea</td>
<td>0.25</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.15</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>1.27</td>
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<tr>
<td>Singapore</td>
<td>2.21</td>
</tr>
<tr>
<td>New Zealand</td>
<td>2.71</td>
</tr>
<tr>
<td>China</td>
<td>3.07</td>
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<tr>
<td>Canada</td>
<td>3.25</td>
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<tr>
<td>Netherlands</td>
<td>3.36</td>
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<tr>
<td>U.S.A.</td>
<td>3.53</td>
</tr>
<tr>
<td>Germany</td>
<td>4.42</td>
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</tbody>
</table>

Source: Kushida, K. and S.-Y. Oh, 2006
Ultra Broadband and FTTH Networks

- Fixed costs for adding FTTH in existing neighborhoods is about $821 per household.
- The variable costs of premise equipment for each subscriber is c.$600.
- The total cost per subscriber is lower when there are more subscribers. The service is profitable with high monthly Revenue Per User (RPU).
- But it can take several years to reach 35% penetration rate.
- Ultra broadband stockholders are patient enough?

Source: Comming Cable Systems, 2003
Because of high costs, telcos do not install their own FTTH networks.

In the US, the FCC’s rules that eliminate the requirement to share access with competitors provides more incentives to telcos to invest in these technologies.

Theoretical studies demonstrate that monopoly power obtained by not sharing their network is an incentive to innovation.
Constraints for ultra broadband development (II)

- In theory, bundling (more services sold together) increases the prospects for a profit potential (higher RPU).
- But competition makes it more difficult to add services and also limits the take rate of a single provider.
- New innovative services that exploit ultra Broadband would help increase RPU, but many of them have not been developed yet and are waiting for more subscribers to faster networks – the chicken vs. egg dilemma.
- When several competitors fight for the same customers with their own network the opportunity for profit is small and the ultra broadband deployment slower.
The US ultra broadband environment

- The new AT&T and Verizon plan to install more new FTTH networks (after FCC have announced that the new regulations eliminate the requirement to share access to those networks with competitors).
- More investment and standardization of FTTH technologies drives prices down.
- Because of the pressures on profit potential, telcos’ strategy will be to cherry-pick the most profitable opportunities and only install FTTH in new neighborhoods.
- This will leave older neighborhoods, urban housing, and rural environments without access to ultra Broadband.
- The digital divide may become a more serious problem.
- Policy makers should ensure that the cities will not suffer from aging infrastructure.
- Many alternatives, among them Public ultra Broadband may be a possibility.
Theoretical Basis of the Economic Impact of Broadband Technologies

Investment in ultra bb is driven by demand

More use of application & services drives demand for ultra bb

Improved networks support innovations in new services & applications
Forecasting Models for ultra broadband demand and deployment

- There are many categories of models used to forecast demand and/or technology deployment.
- They are categorized as:
  - Econometric analysis
    - Time-series (moving average, exponential smoothing, trend analysis)
    - Causal (single and multiple regression analysis)
  - Qualitative or Business models
    - Delphi
    - Jury of Executive opinion
    - Sales force composite
    - Consumer market survey.
The models used for forecasting ultra broadband are:

- Discrete choice econometric approach (Forman, 2005)
- Logit models – analyse the probability of broadband connection in a given year by a user (firm or consumer, Ordanini, 2006).
- Duration or hazard models (Cameron and Trivedi, 2005)
- Diffusion models.
Factors affecting ultra broadband demand and applications

- There are three types of factors which are likely to drive broadband connection and use of broadband-based applications among firms:
  - Firm-specific characteristics
  - Location-specific factors
  - Time-specific factors.
Firm-specific characteristics and ultra broadband demand and applications

- Firm-specific characteristics
  - availability of tangible (i.e. financial) and intangible (i.e. managerial competencies) capital
  - greater ability to access external resources and markets
  - competitive pressures in the industry
  - greater availability of complementary ultrabroadband services (Forman, 2005).
Location-specific characteristics & ultra broadband demand and applications

- **Location-specific characteristics**
  - rural vs. urban areas (broadband connection is less likely in rural areas (Prieger 2003, & Tookey *et al*. 2006 for residential demand and Arbore and Ordanini, 2006 for business demand)
  - income of a geographic area and education are likely to affect positively the demand for broadband (Prieger 2003)

- Broadband penetration is positively correlated with urban population density (*Kim et al.*, 2003).
Time-specific characteristics and ultra broadband demand and applications

- Time-specific characteristics
  - price of a new technology
  - expected variation of price over time

- Ceteris paribus, high prices as well as expectations of a decrease in future prices slow down the diffusion process (Stoneman 2001).
Theoretical models linking BB to key economic variables

**Demand factors**
- Population density
- Education
- Price

**Cost factors and market conditions**
- Cost of alternative technologies
- Competition
- Oligopoly

**Regulatory factors**
- Unbundling – facilities and service based competition
- Types of regulation (RORR, PCs)

- Hedonic demand models
- Lancaster characteristics
- Profit and cost functions
- Game theoretic models
- Multivariate models
- Profit functions

BBD = f(price, education, density, direct regulation of basic services, indirect regulation and unbundling, tax incentives, subsidies, loans, etc)

i.e., PCs combined with low UNEs ↓ DSL BBD but ↑ BBD by cable
<table>
<thead>
<tr>
<th>Study</th>
<th>Demand factors</th>
<th>Cost &amp; market factors</th>
<th>Regulatory factors</th>
<th>Other policy factors</th>
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<tbody>
<tr>
<td>Bourreau &amp; Dogan (2005)</td>
<td></td>
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<tr>
<td>Denni &amp; Gruber (2005)</td>
<td>↑ (inter-platform competition)</td>
<td>↑ (intra-platform –DSL- competition in the s.r. but not in the l.r.)</td>
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<td>Distaso et al. (2004)</td>
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<td></td>
<td></td>
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<tr>
<td>Flamm (2005)</td>
<td>BB ↑ Income, population density, geography</td>
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<tr>
<td>Howell (2002)</td>
<td></td>
<td>Local unbundling ↓ BB Inter-modal competition ↑ BB (OECD)</td>
<td></td>
<td></td>
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<tr>
<td>Hu &amp; Priefer (2007)</td>
<td>↓ (inter-platform competition)</td>
<td></td>
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<tr>
<td>Lehman &amp; Weisman (2000)</td>
<td></td>
<td>Low UNE prices</td>
<td>↓ (price caps)</td>
<td></td>
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<tr>
<td>Maldoom et al. (2003)</td>
<td>↑ (inter-platform competition)</td>
<td></td>
<td></td>
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<tr>
<td>Plykalas &amp; Vlahos (2006)</td>
<td>↑ (no distinction in competition)</td>
<td></td>
<td></td>
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<tr>
<td>Priefer &amp; Lee (2006)</td>
<td>Low UNE prices (unbundled network elements)</td>
<td></td>
<td>BB ↑ when price cap regulation</td>
<td></td>
</tr>
<tr>
<td>Priefer (2001 &amp; 2003)</td>
<td>BB ↑ Income, education</td>
<td>BB (tech. + services) ↑</td>
<td>BB (tech. + services) ↑</td>
<td></td>
</tr>
<tr>
<td>Wallsten (2005)</td>
<td></td>
<td>Unclear BB↑ with resale and BB↓ with more unbundling</td>
<td>Universal service via tax &amp; subsidies ↓ BB</td>
<td></td>
</tr>
<tr>
<td>Wallsten (2006)</td>
<td>BB ↑ Neutral on speed</td>
<td>BB↓ (sub-loop unbundling)</td>
<td>↓</td>
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</table>
Regulation and Ultra broadband deployment: results of the econometric studies

- Unbundling is an important factor in explaining broadband deployment (Korea and Japan vs. The USA)
- The challenge of the « Stepping-stone theory »
- Subloop unbundling is negatively correlated to broadband deployment
- Low colocation charges discourage upgrades and/or investment in new equipment
- Virtual collocation discourages broadband deployment.
It has been observed that demand for new products and new technologies exhibit a stylized pattern. It starts at low levels to attain a critical mass, then saturation and, in some cases a decline. Although the pattern of this S-shaped curve is quite well known, still important parameters such as the inflexion points are quite important and they have to be estimated with precision.
The Gompertz diffusion model and logistic forecasting model

- The Gompertz model gives an S-shaped curve but it is asymmetric with adoption slowing down as it progresses.

\[ Y(t) = e^{-e^{-b(t-a)}} \]
S-shaped curves for various technologies

- The Gompertz forecasting model
The Logistic or Fisher-Pry diffusion model

- The logistic or the Fisher-Pry diffusion forecasting model takes the following form:

\[ Y(t) = \frac{1}{1 + e^{-b(t-a)}} \]
The logistic or the Fisher-Pry
Broadband adoption and high speed demand

Broadband adoption in Korea and the US

High speed demand by US households

Figure 15: Broadband households by nominal data rate, percentage of households (US)
Usefulness of broadband forecasting models

- Evaluate various broadband technologies
- Develop strategies for broadband roll out
- Establish broadband network platforms
- Forecast the speed of deployment of broadband technologies
- Evaluate the saturation levels of each BB technology in various market segments
- Use financial techniques of NPV and pay back period to evaluate the financial viability for each BB technology
Conclusions (I)

- Econometric models explain the drivers of ultra broadband deployment
- Diffusion models are useful for making long term forecasts about ultra broadband deployment
- Both approaches are complementary
- The lack of historical data for ultra broadband makes the application of both approaches difficult in practice
Conclusions (II)

- Econometric models indicate that
  - Demand (price, population density, education)
  - Cost and supply (availability of substitutes, intermodal and intramodal competition)
  - Regulation (unbundling, low colocation charges, facilities and infrastructure base competition)
- Are important factors in explaining ultra broadband deployment.
- More studies and better data are needed to improve on the results.
- Current findings are preliminary and should be taken with a grain of salt.