

The Century of Infinite Bandwidth

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Popular View of Internet

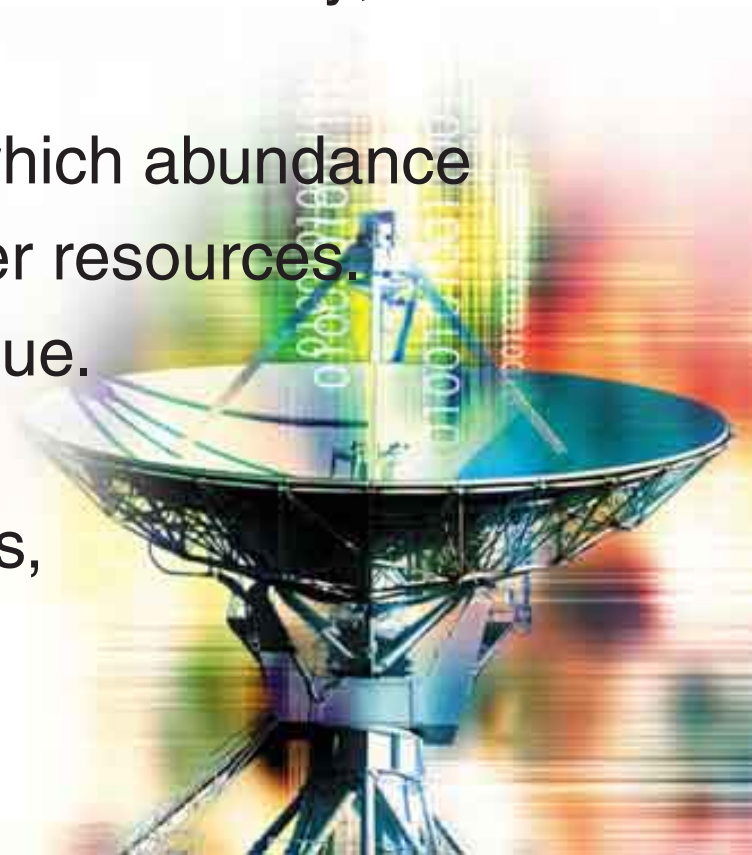
- Global Internet Traffic grows 10% to 12% per month which implies 30 to 60 times growth in 3 years, 300 to 900 times in 5 years.
- Internet users will grow from 200 Million to 1 Billion users in 5 years, the annual growth will leap from 25% to 38%, using PC, mobile phone, PDA or IA.
- End-to-end bandwidth will increase from 50 Kbps to 5~20 Mbps (100 to 400 times growth).
- Revenue from e-Commerce will double every year which will reach US\$1.4 Trillion by 2003.





Visionary View of Internet

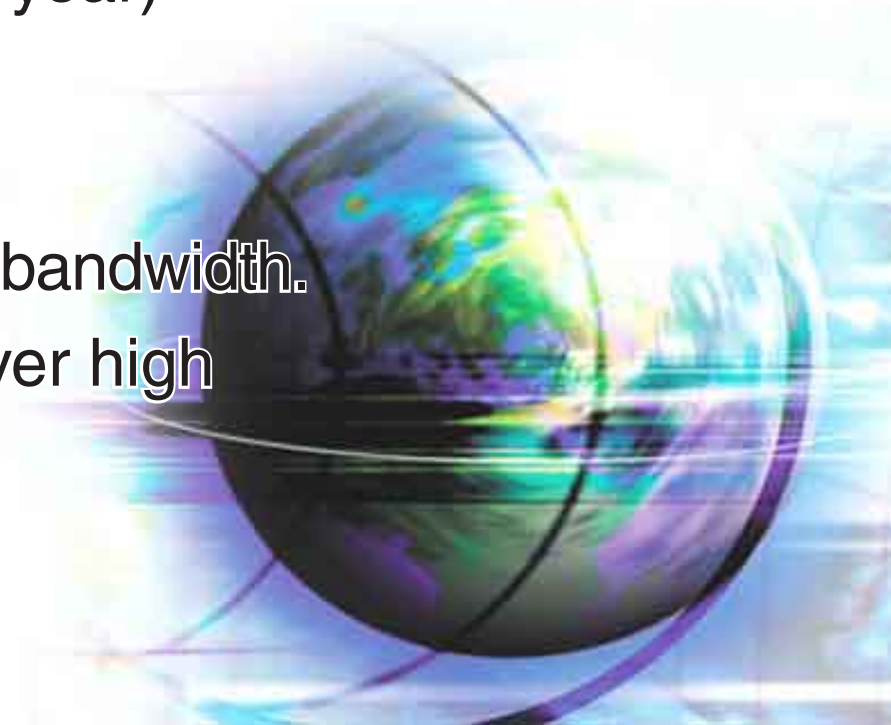
- Voice, data and video over a single Internet Protocol (IP) delivering all kinds of services via PC or information Appliances (IA).
- Internet will be *Always-On* just like water and electricity; Everywhere like the air.
- Internet will drive knowledge economy in which abundance knowledge capital is more critical than other resources.
- Internet is a paradigm shift and survival issue.
- Foundation for new Service and Business models in E-commerce, multimedia, movies, music, education and health, etc.





How to build an Internet Society?

- Employ abundance resources to drive the Internet revolution:
 - Infinite Bandwidth
 - Open-source Software
 - Knowledge Contents (2×10^{18} Bytes/year)
- Scarcity v.s. Abundance
- Deregulation v.s. Leapfrog
- The biggest obstacle is the high cost of bandwidth.
- But, there is a far cheaper way to deliver high speed Internet!



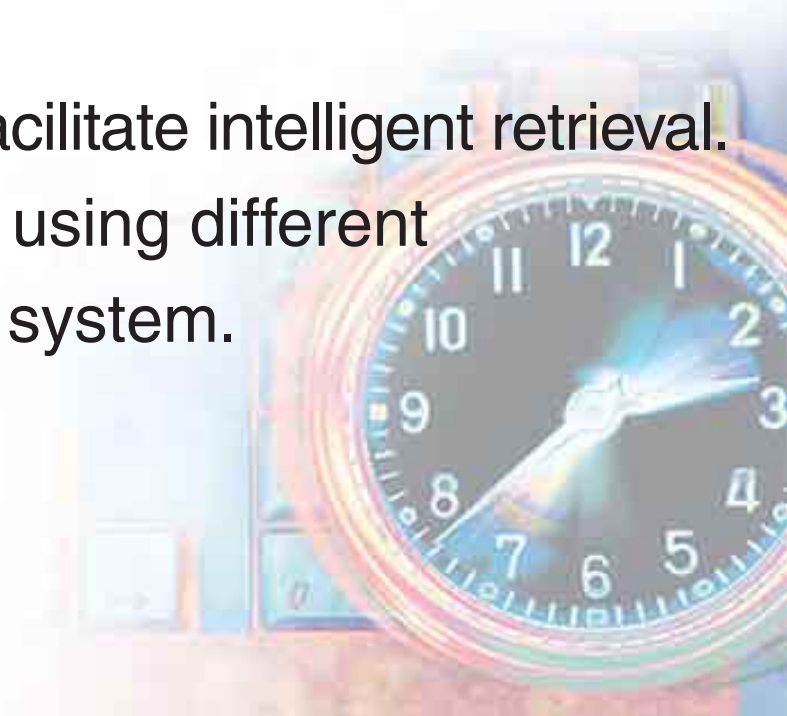


Cathedral and Bazaar

- Self-organised software development paradigm
- Linus' Law: Given enough eyeballs, all bugs are shallow!
- However, finding the problem is a bigger challenge than solving problem.
- Insight comes from individuals and the paradigm shifts of Internet and service model will still drive the spontaneous Bazaar style for truly innovative work.

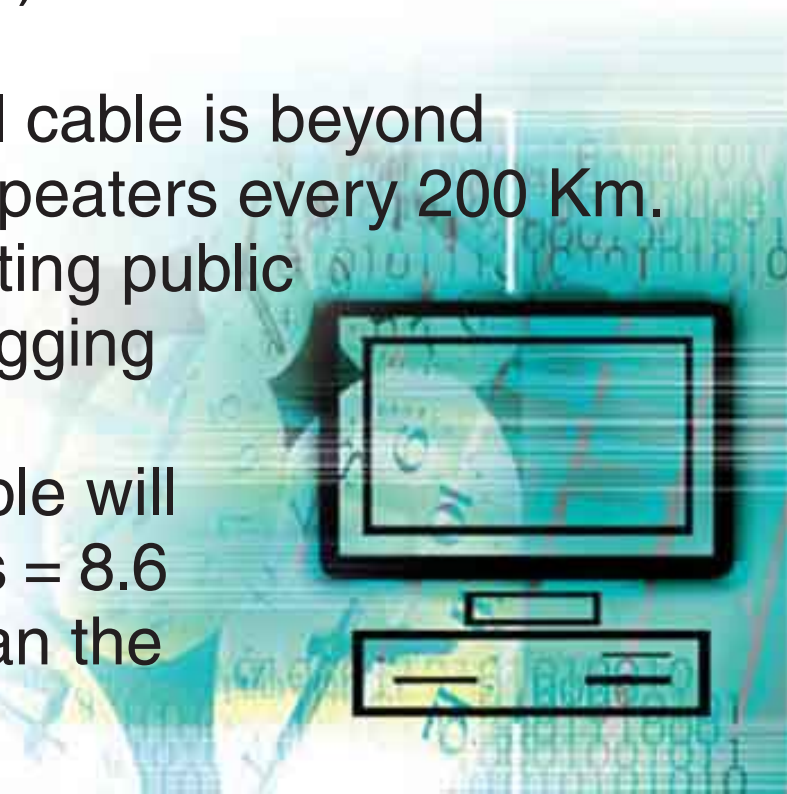


Knowledge Contents

- Contents needs knowledge structure, may use metadata to achieve it.
 - Contents given with structure and organisation.
 - Focus on the analysis of knowledge & management aspects.
 - Emphasise 3 axes: Spatial, Temporal & Knowledge Structure;
3 subjects: People, Object & Event.
 - Employ Relationship Analysis to enable/facilitate intelligent retrieval.
 - Concentrate on content description and using different levels to present knowledge structure & system.
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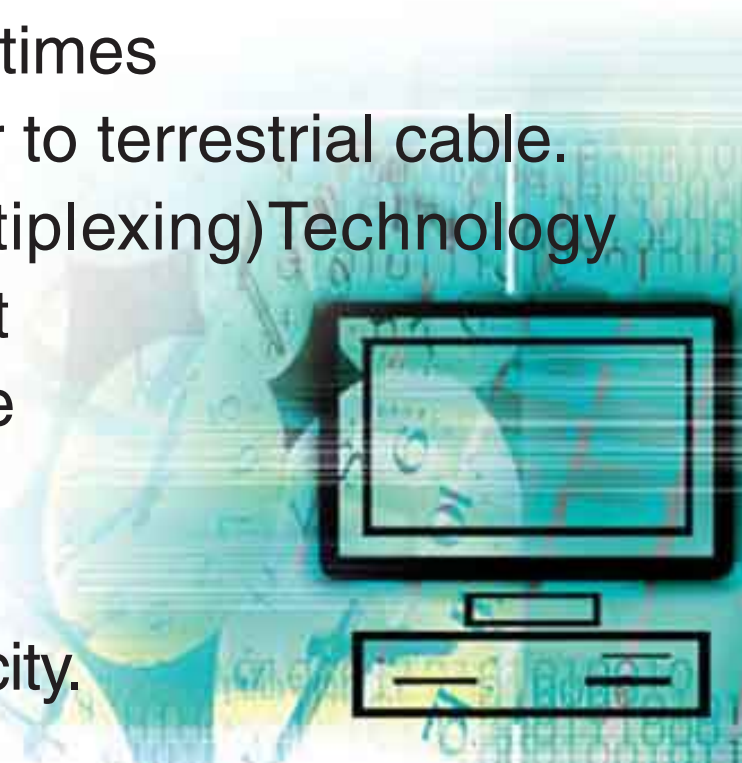


Optical Fibre Paradigm Shift

- The first submarine optical-fibre cable was installed in 1988. Massive construction of submarine and terrestrial cables after 1996 when Internet became mainstream of communication.
 - In the future, the backbone network will only adopt submarine and terrestrial fibre-optic cables. Furthermore, the last mile to the end users will possibly be Fibre to Home (FTH).
 - Terrestrial cable:
 - The speed of advanced G655 terrestrial cable is beyond 40GBbps (OC768) which only needs repeaters every 200 Km.
 - The cost of the infrastructure using existing public conduits is about NT\$600K/Km; road digging will cost additional NT\$5M/Km.
 - The bandwidth of a single terrestrial cable will exceed $10\text{Gbps} \times 1000\lambda \times 864\text{fibres} = 8.6$ Petabits which is millions times faster than the current OC48 (2.4Gbps).
- 



Optical Fibre Paradigm Shift (cont'd)

- Submarine cable:
 - Needs repeater several hundred Km, which weighs several hundred Kg. So, it requires 10KV DC power sent fromland. This severely restrict the number of fibres in the cable, typically, 4 pairs (8 threads). DWDM is the only solution to increase the bandwidth which may grow hundreds of times
 - The cost is about NT\$500K/Km, similar to terrestrial cable.
 - DWDM(Dense Wavelength Division Multiplexing)Technology
 - Simultaneously transmitting different wavelength (colour) of light in the same optical fibre. Since different colours of light are independent from each other, this would increase the transmitting capacity.
- 




Characteristics of Internet Traffic

- Fractal traffic (self-similar) or bursty at all traffic volumes.
- Very asymmetric with ratios of up to 16:1 between transmit and receive paths.
- Congestion at the edge.
- Dominated by computer to computer traffic
 - Computer to computer traffic can easily tolerate packet loss, latency and jitter.

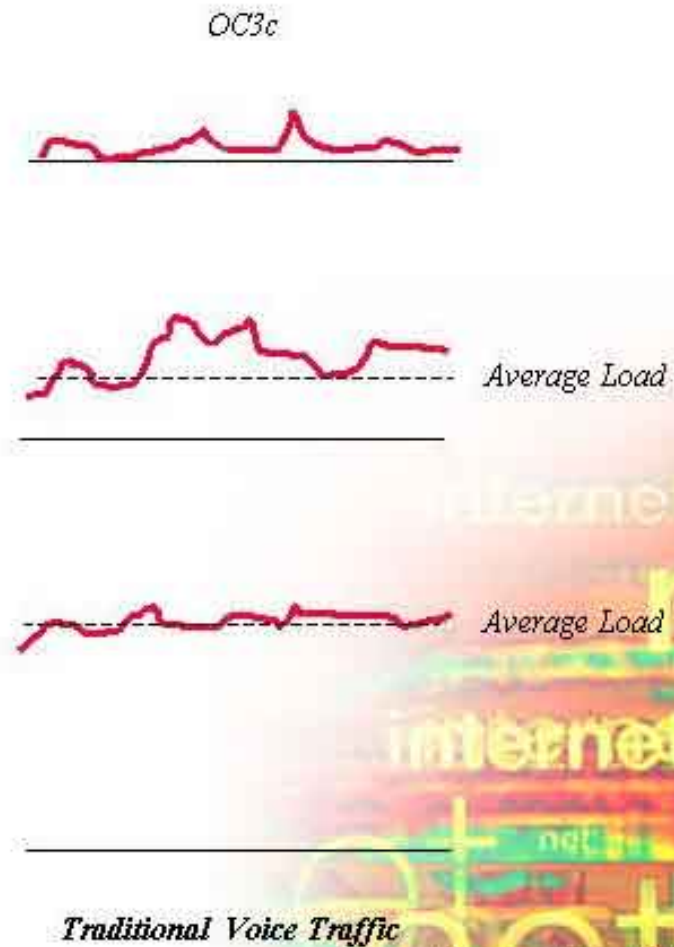
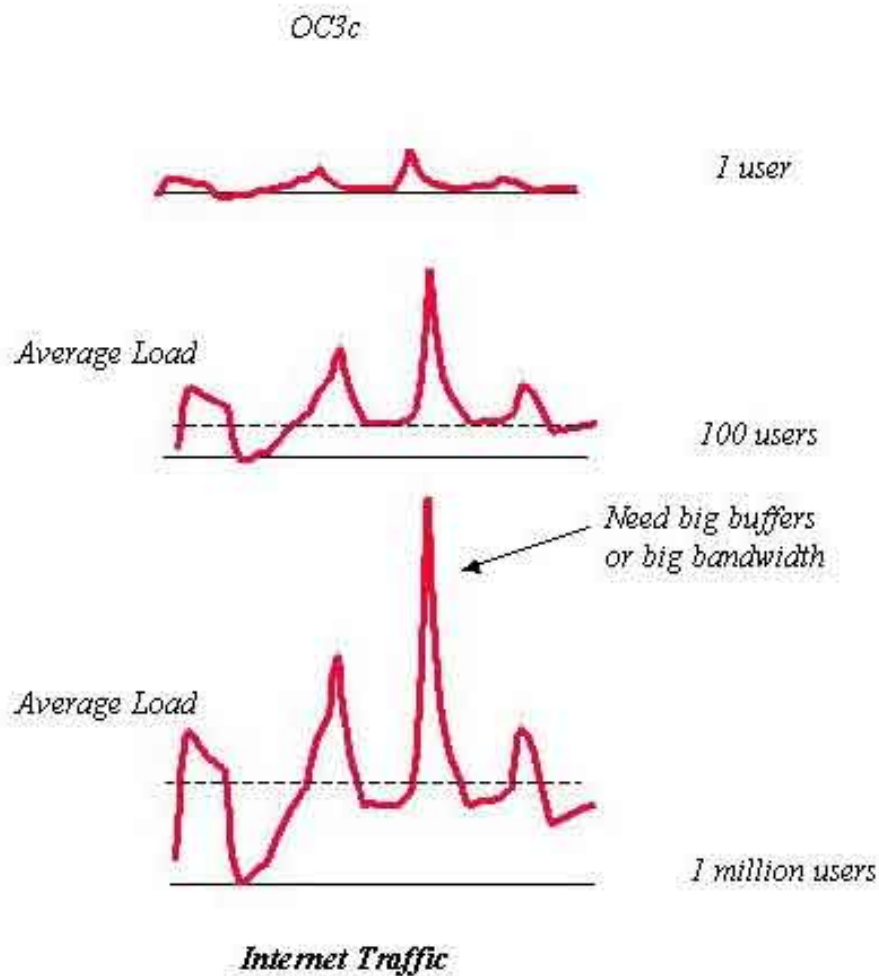




Characteristics of Internet Traffic (cont'd)

- Server performance, DNS, routing tables, etc have bigger impact on Internet reliability than the underlying physical network
 - Physical network reliability contributes to less than 40% of overall Internet outages and delays.
 - Multiple connections to Internet is more reliable than one connection with 99.999 reliability.
 - Scalability is about the number of TCP/UDP sessions, compared to number of phones in telecom network.
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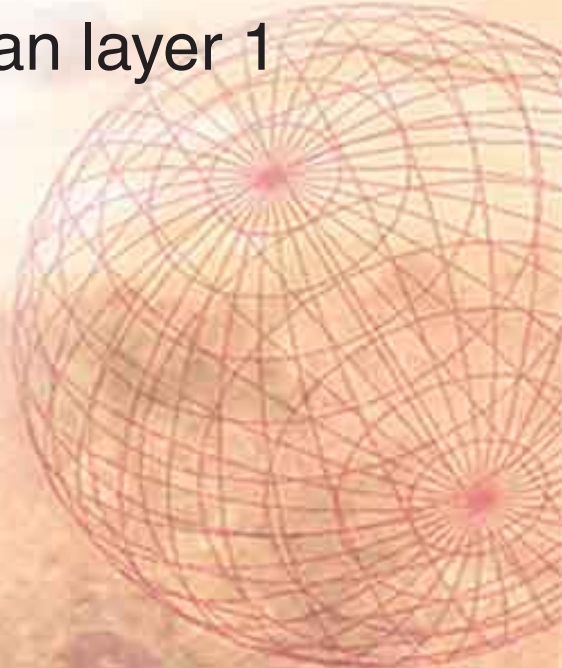
Fractal Internet



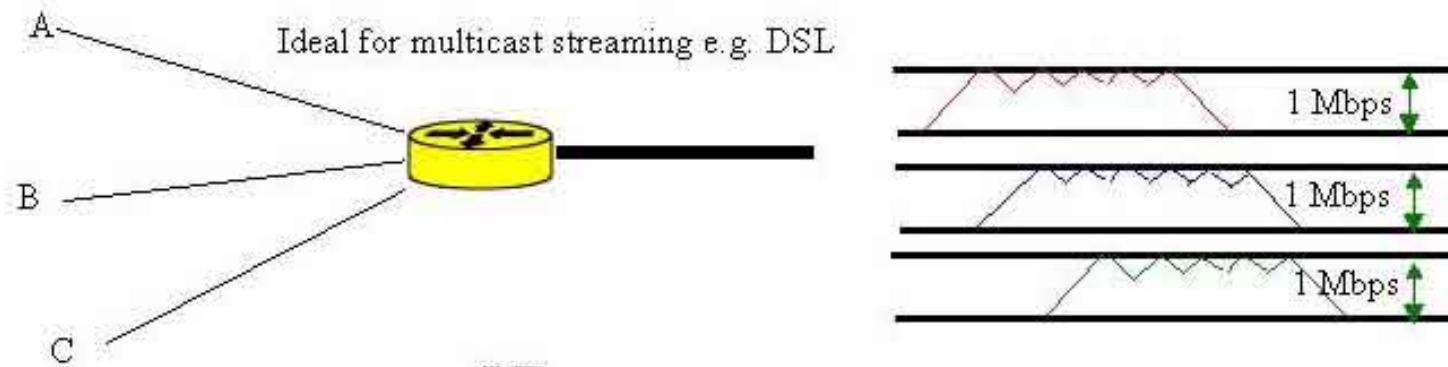
Source: CANARIE



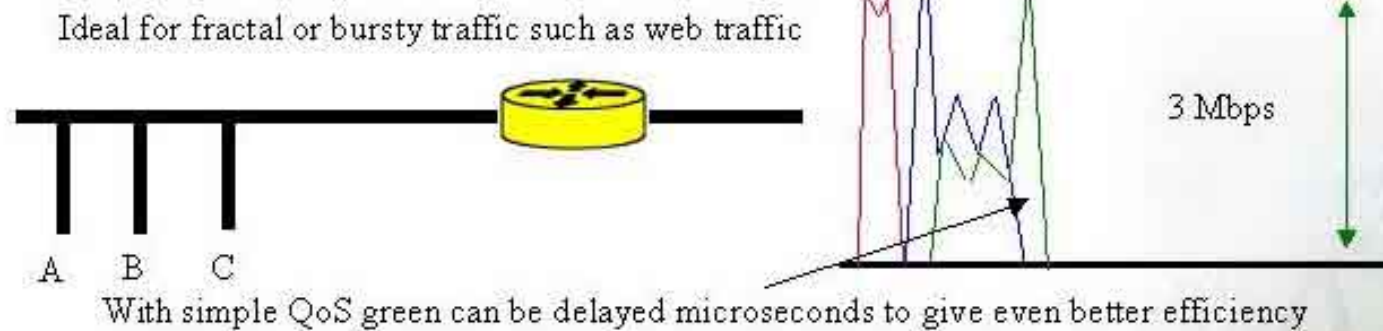
Implications of Fractal Bandwidth

- With fractal bandwidth reserved bandwidth channels causes more
 - congestion than one shared channel of equivalent bandwidth.
 - In the Internet it is more important to prioritise traffic by packet loss and latency rather than by reserved bandwidth.
 - Layer 3 restoral mechanism make more sense than layer 1 restoral and protection with highly fractal traffic.
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Bandwidth Models



OR



With simple QoS green can be delayed microseconds to give even better efficiency

Source: CANARIE

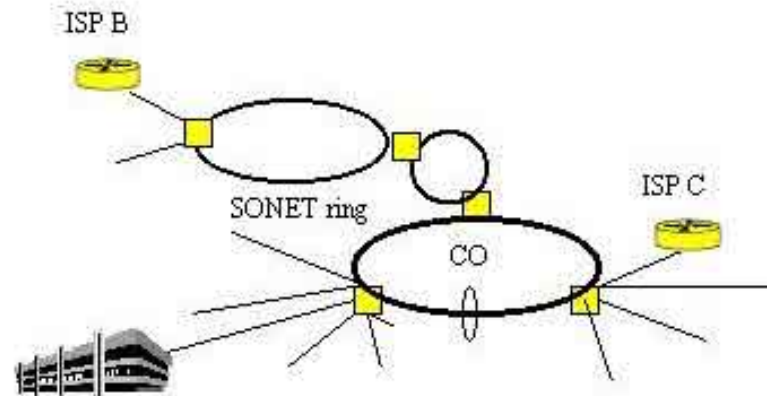




What is an Optical Internet?

- WDM fibres where individual wavelengths are the link layer interconnect.
- High Performance Router acts as the main switching routing device instead of SONET/SDH switched.
- Use intrinsic self healing nature of Internet for redundancy and protection (don't require SONET/SDH layer).
- Traffic engineering and network management done via MPLS (Multi-Protocol Label Switching).
- It will fundamentally change the traditional carrier-customer relationship.
 - Allow LAN economics and engineering concepts to invade the WAN.
- These new concepts in optical networking are starting from the university and research community again.

2 Different Views



Telco Network

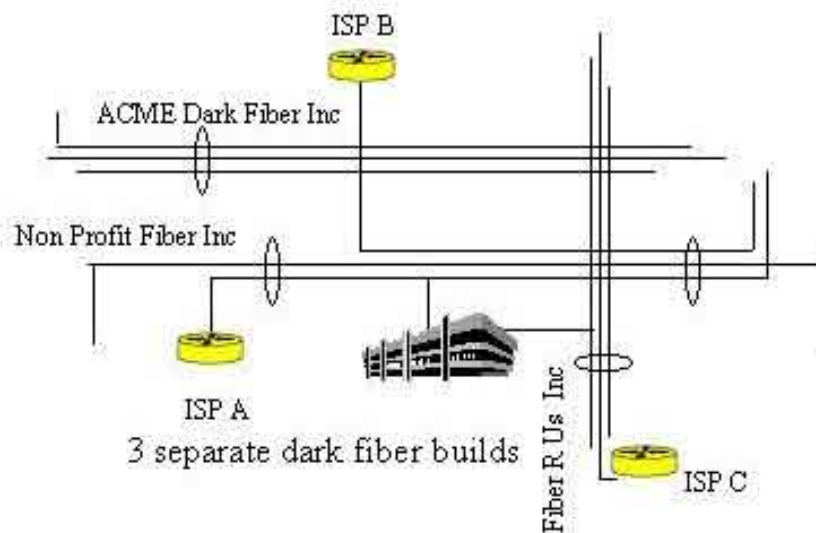
“Ring of Rings”

99.999% reliability only in the SONET

Ideal for carriage of legacy traffic

“Highest” common denominator technology and pricing

Driver is bandwidth efficiency



Customer Empowered Network

“Warp and Woof”

Separate dark fiber networks built by different competing organizations

Customer responsible for building rings and establishing reliability

Ideal for LAN and Internet traffic

Driver is congestion avoidance

Source: CANARIE

Dark Fiber versus SONET

- Customer owned dark fiber
 - Low equipment costs – mostly fused fiber, rarely any active devices
 - Low labour costs – only fiber maintenance
 - Fiber technology does not change
 - Costs can be amortized over 20 years
 - Most costs are capital vs operational
 - The only true future proof technology
 - Reliability obtained through purchase of 2 separate dark fiber route or wireless link, etc
 - Can take advantage of economies of scale with large fiber builds
 - Simple extension of LAN network
 - Unlimited bandwidth
 - “Good enough” is adequate for single entity
- Carrier SONET network
 - High equipment cost – SONET muxes, etc
 - High labour costs for SONET muxes, CPE equipment etc
 - Equipment changes every 5 years
 - Costs must be amortized in 5 years
 - SONET soon may be replaced by GbE, DPT
 - Requires SONET ring to deliver 99.999 reliability
 - Limited economies of scale with larger SONET OC-192
 - Customer can not “capitalize” carrier service
 - CPE equipment required from LAN to WAN
 - Common carrier needs “perfect” network

Source: CANARIE

Driver for Dark Fibre

- Low cost
- LAN invades the WAN - no complex SONET or ATM required in network
 - Network Restoral & Protection can be done by customer using a variety of techniques such as wireless backup, etc
 - Most Internet reliability problems are NOT network related
 - Bandwidth demand is being driven by congestion avoidance

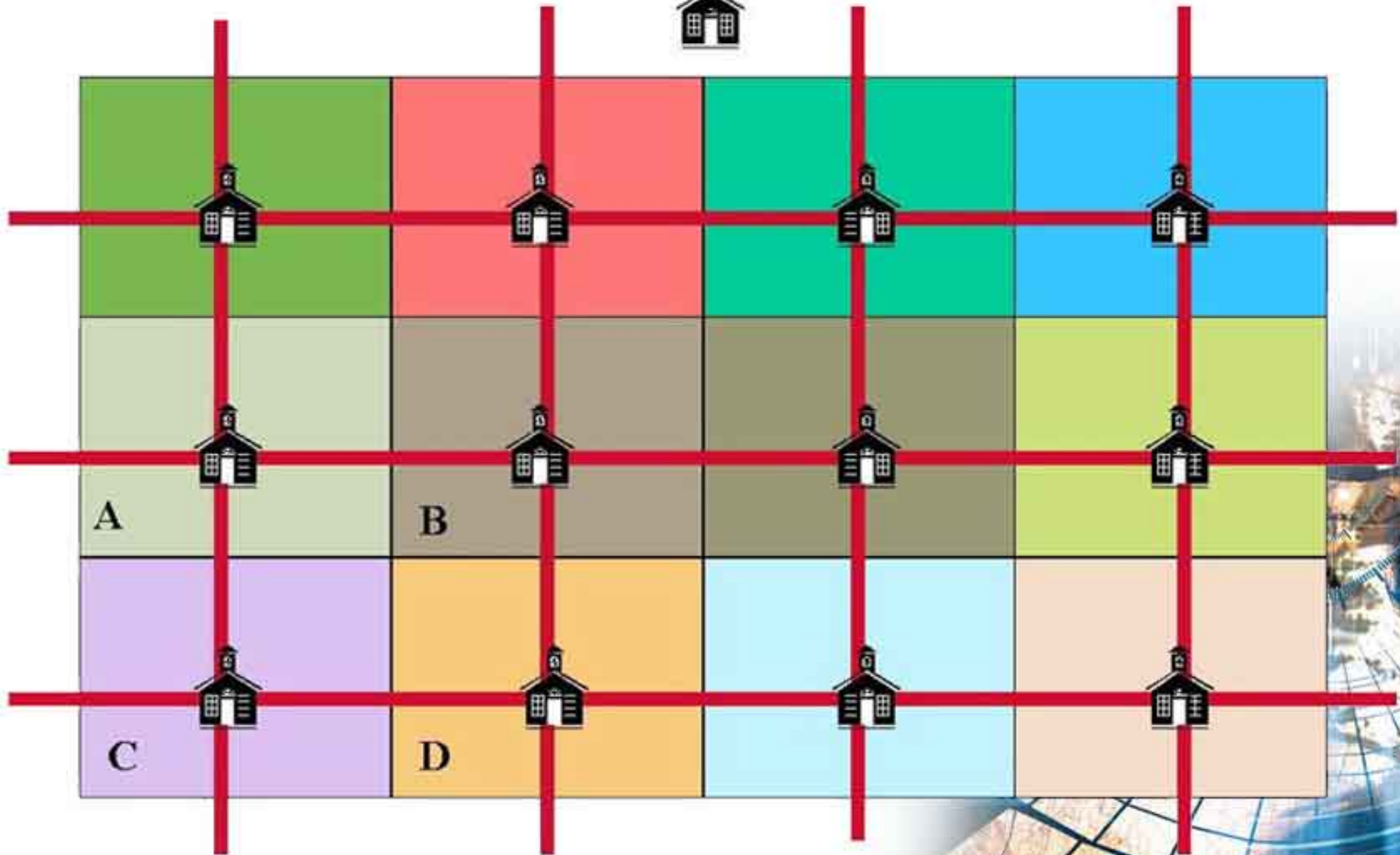
Driver for Dark Fibre (cont'd)

- Enables new applications and services not possible with
- traditional telecom service providers
 - Relocation of servers and extending LAN to central site
 - IP telephony in the wide area
 - HDTV video
- Customers will start with dark fiber but will eventually extend further outwards with customer owned wavelengths
 - Extending the Internet model of autonomous peering networks to the telecom world

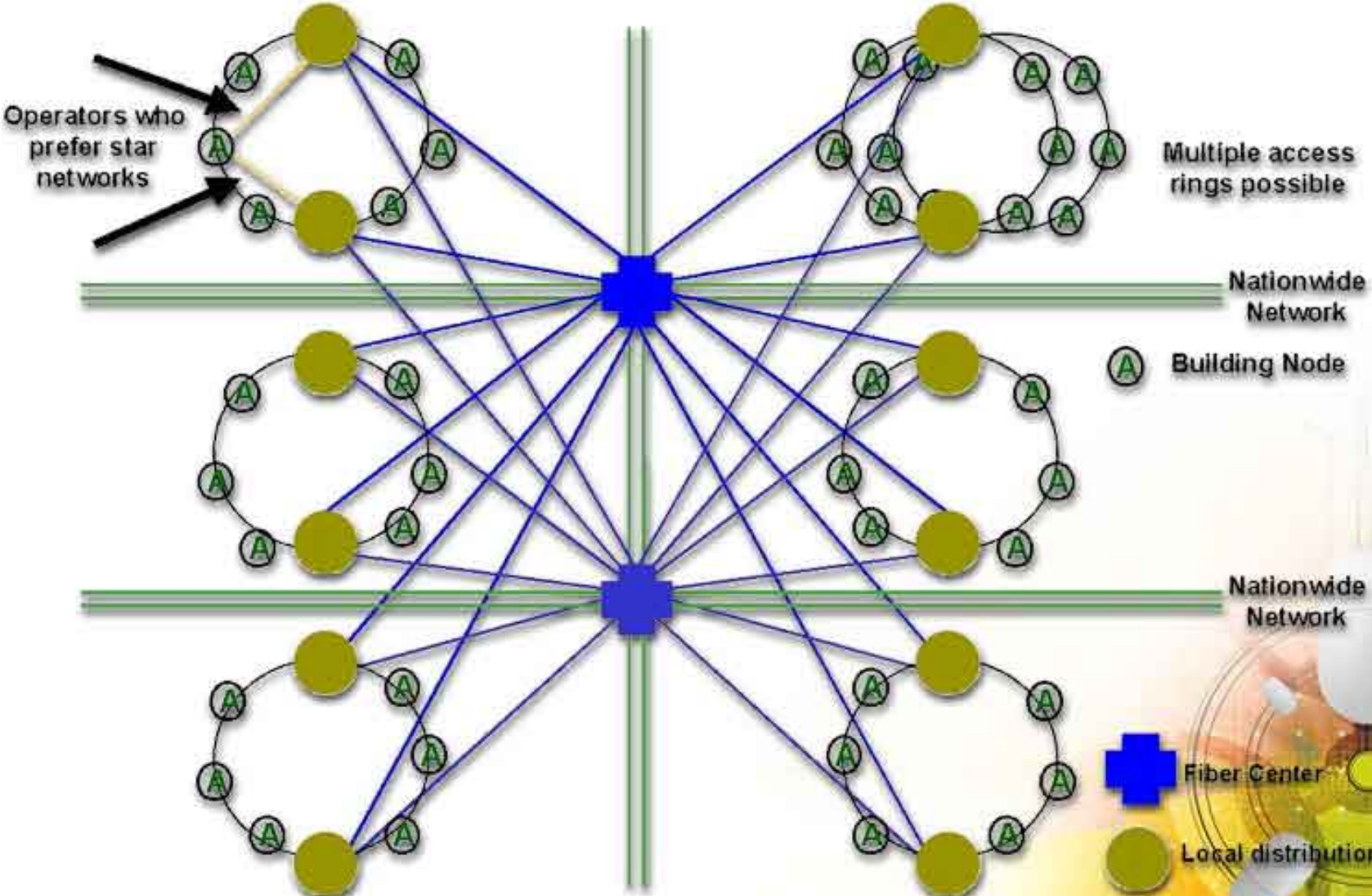
National Topology

700 Fibers

Fiber Center



Distribution Network



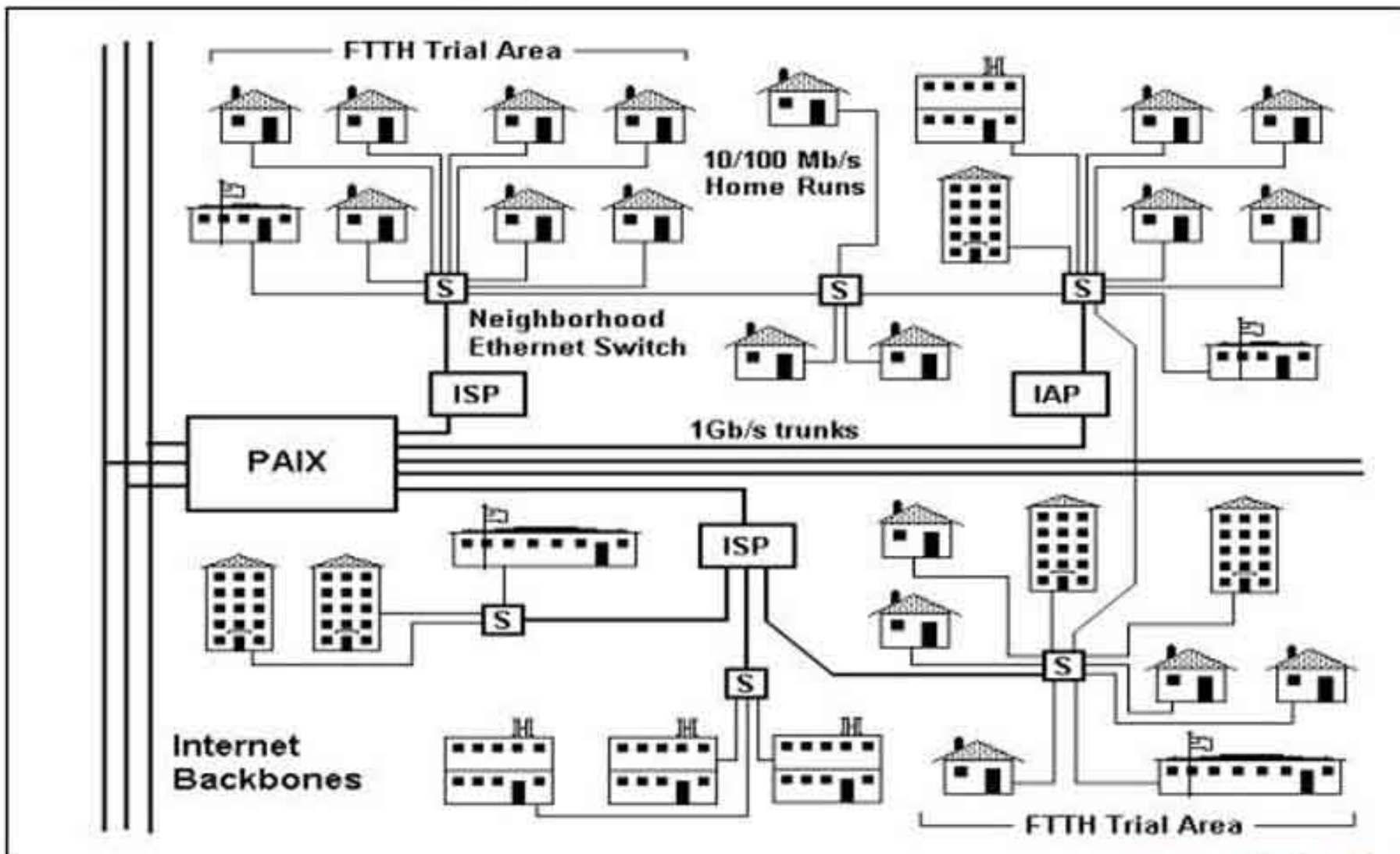


Visions from Municipal Infrastructure

- Economic Development
- Advanced Infrastructure
 - Abundant Bandwidth
 - Open Platform
- Nurturing Competition
- Universal Availability
- New Services



Palo Alto Fiber To The Home Trial



Source: CANARIE

Taiwan Optical Internet Perspective

- Initiate Optical Internet Consortium (OIC) which plan, design and implement Optical Internet vision.
- OIC structure: xx board members, public sectors and private sectors are involved to negotiate the consortium structure, members' rights and liability.
 - Policy making goals: increase nationwide core value, regulating & licensing
 - Research and Education goals: own an IRU (irrevocable right of use) capacity on the network, or own a portion of the network.
 - Commercial goals: deliver optical Internet service for business.

Taiwan Optical Internet Perspective (cont'd)

- Build national dark fiber with DWDM/CWDM in partnership with a carrier who wants to offer dark fiber or optical Internet services to business and home.
- Build production networks.
- Long haul revolution: Use 10Gigabit Ethernet technology for long haul. GE may be marginally more expensive than xDSL or cable model, but with 1000 times the bandwidth!!!
- Enables new applications and services not possible with traditional telecom service providers.
- The future telecommunication's world may be dominated by thousands of customer owned network that peer at the physical as well as virtual level.



Conclusion

- Many governments have recognised the importance of access to low cost dark fiber as fundamental economic enabler.
- Swedish government is building public fibre infrastructure (\$12 Billion) after it deregulated Telecom Industry and privatise Swedish Teli.
- Over 100 municipals in the US are deploying dark fibre networks.
- R&E network is a core ingredient and drive of Optical Internet.
- Developing countries must take advantage of Internet network principles and abandon the old Telecom's way of thinking!