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Exploration Programmes:
Corporate Technology Explores Future Telecommunications

10 Gigabit Ethernet – Breaking the LAN/MAN/WAN Barriers

Nowadays, the need for higher speeds in the Internet access is driven by the emergence of new bandwidth-consuming applications and the Internet becoming more and more widely deployed among private and business customers in metropolitan areas. As an answer to those needs, the new generation of Gigabit Ethernet offers higher performance compared to other non-optical technologies as well as passive optical networks (PON). It provides low cost, ease of implementation on existing fibre equipment, and distances up to 100 km without optical regeneration. Hence, Gigabit and 10 Gigabit Ethernet become competitive with optical Metropolitan Area or Wide Area Network technologies like SDH or ATM.

The Exploration Programme "Broadband Communication Opportunities" explores new broadband service and communication opportunities enabled by the new 10 Gigabit Ethernet technology, managed all-optical networks, the evolution from ADSL to broadband heterogeneous access networks (fixed and mobile/wireless) and peer-to-peer network models.
With its Exploration Programmes, Corporate Technology is exploring telecommunication technologies and new service possibilities with a long-term view of 2–5 years. Further, the expertise built up in the course of this activity enables active support of business innovation projects.

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In the past few years, the Internet has been facing a dramatic increase of bandwidth requirements to guarantee an acceptable quality of service. The content consists no longer of text and pictures only, but also of high-bandwidth real-time streams such as audio and video (e.g. MPEG-4) that suffer from the well-known "best-effort" delivery of the Internet. The ongoing demand for new generic and personalised services increase this bandwidth consumption. However, this trend does not exessively affect the core network which can be over-provisioned up to several 10 Gbit/s thanks to optical technologies like DWDM. It more affects the access and MAN networks, not only due to the smaller bandwidth availability, but also because 70% of the Internet traffic stays in the same metropolitan area, which is causing the so-called "metro bottleneck" [1].

Running over optical fibre, Gigabit Ethernet will compete with traditional MAN/WAN technologies such as SDH. Fully compliant with IP and ubiquitous in Local Area Networks (LAN), it shall in the future be used as a high performance end-to-end protocol to provide seamless quality of service at a competitive price.

The explosion of Internet bandwidth demand with the convergence of data, voice and multimedia streams on IP-based services shows the need for an "IP compliant" technology, more scalable and easier to manage than for example ATM, and able to deliver high performance in the MAN at a reasonable price. On one hand, Ethernet has been improved to offer up to 1 Gbit/s and is thus pushed into the metropolitan area. On the other hand, the availability of dark fibre and its dropping prices blur the demarcation between MAN and WAN. In this context, the arrival of 10 GbE (Gigabit Ethernet) running over optical fibres turns out to be the perfect solution for the MAN, because it merges the advantages of both classical Ethernet and fibre: high bandwidth, low cost, simplicity, and ease of use with IP. Moreover, the wide deployment of Ethernet at the edge of the networks and the "friendliness" of 10 GbE to SDH make it easy to migrate the existing infrastructures towards a seamless Ethernet-based integration of LAN, MAN and WAN areas.

The Evolution of Ethernet

Ethernet is known as a well proven network technology in the office environment (LAN). While GbE continues to be simple, mature and compliant with the IEEE 802.3 standard, it is clearly distinguishable from its ancestors. The 1000-fold increase in speed from 10 Mbit/s to 10 Gbit/s is the most obvious change;

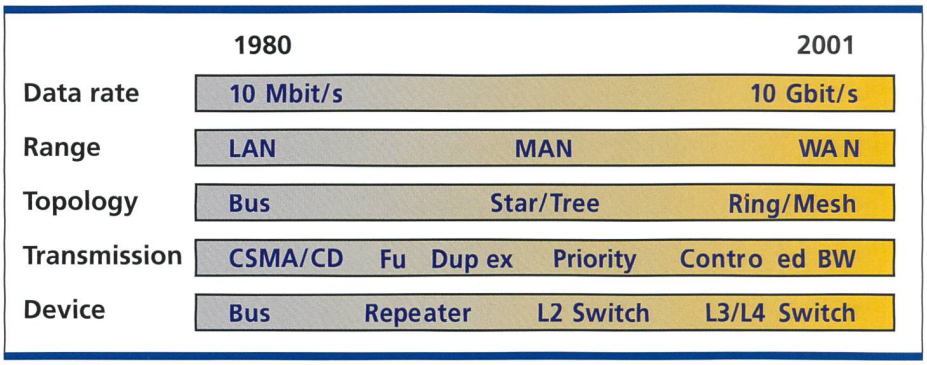

Fig. 1. The evolution of Ethernet.

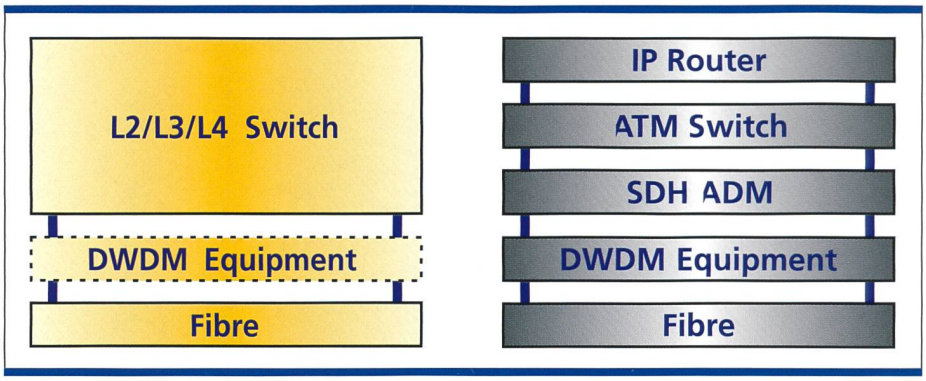

Fig. 2. Data network equipment: Ethernet-based (left) and SDH-based (right).

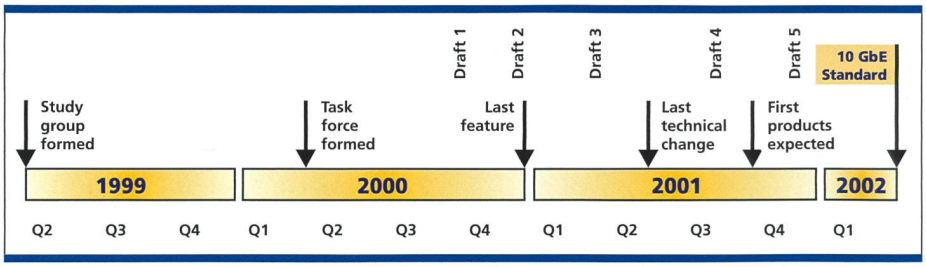

Fig. 3. 10 Gigabit Ethernet standardisation schedule.

many other changes were made which are not as obvious (fig. 1).
Previously based on transmission over copper, Ethernet now runs over fibre and available GbE equipment allows point-to-point distances of over 100 km. The proposed standard for 10 GbE calls for a minimum distance of 40 km, using standard single mode fibres. This distance is already large enough to build networks in the metropolitan area.
The classical topology for Ethernet is a bus shared by all workstations. Hence, the bandwidth is also shared between them. Messages sent at the same time by different workstations collide and must be retransmitted after a certain time using CSMA/CD (Carrier-Sense Multiple Access with Collision Detection). With the introduction of layer-2 switching and full duplex transmission, collisions of data frames could be avoided, allowing the full bandwidth to be used, which resulted in a network migration to a star tree topology.
Today, layer-3 and -4 switches are entering the router domain. Their additional routing capabilities allow to deal with data on a per application basis (TCP/UDP port). Paired with priority mechanisms such as IEEE 802.1p or DiffServ, and protocols for controlling bandwidth such as the Resource ReSerVation Protocol (RSVP) and Common Open Policy Service (COPS), this is the precondition to offer QoS (Quality of Service) in Ethernet networks. The routing capabilities also enable the realisation of arbitrary network topologies including ring and full-mesh structures. For ring topologies, there also exist emerging layer-2 protocols such as the IEEE 802.17 Resilient Packet Ring (RPR) protocol, which for redundancy add a protection mechanism with very short fail-over times.

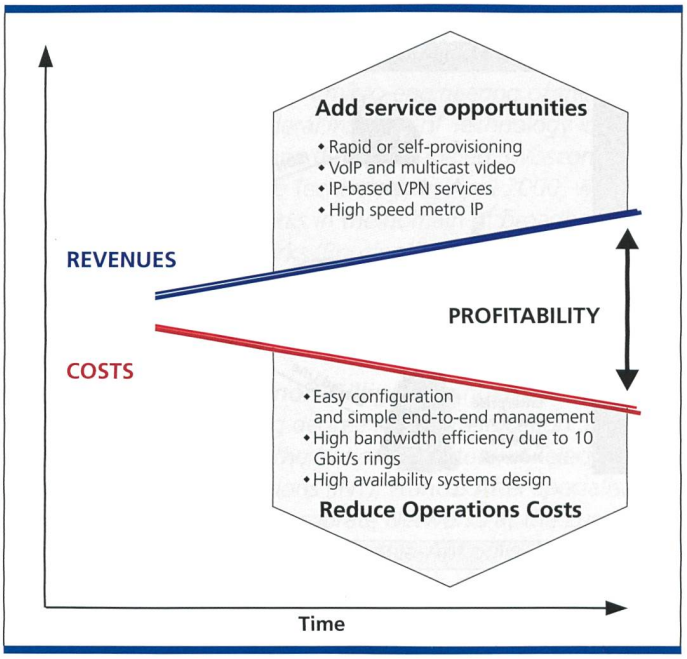

Fig. 4.
Gigabit Ethernet value proposition.

The Motivation for Introducing 10 GbE

10 GbE is very well suited to marry packet networks to the optical network layer. Therein lies one of the motivations for pushing 10 GbE into the MAN and WAN: Since 95% of all IP traffic originates on Ethernet, in many cases it would make sense to implement an end-to-end Ethernet. This way, protocol conversions and QoS parameter mapping become obsolete, while overall simplicity increases dramatically. Especially the QoS parameter mapping is not trivial in existing heterogeneous networks [2]. For example, Ethernet priority (802.1p) is mapped onto layer-3 priority such as DiffServ, which in turn is mapped onto the Shim Header Experimental Field ("EXP") of MPLS.
Ethernet is very scalable and compatible with the existing network infrastructure. Granularities of 10/100 Mbit/s, 1 and 10 Gbit/s allow a very flexible service provisioning. When comparing the average equipment price per Gigabit of bandwidth, 10 GbE is by far the least expensive technology, 10 times cheaper than SDH STM-64, which offers the same bandwidth [3].
Regarding the protocol stacks implemented in hardware equipment, an end-to-end Ethernet reveals its simplicity compared to classical data networks as shown in figure 2.

Technology Facts

The two main points of the IEEE 802.3ae standard for 10 GbE are the full duplex operation and the transmission over fibre. With this, the shared medium and shared bandwidth eras are definitely gone. Paired with wire-speed switching devices (e.g. devices being able to handle the full load on ports) and priority mechanisms, this is the enabler for QoS in an end-to-end Ethernet environment. Further novelties include a new coding scheme (64B/66B), which introduces only 3% of overhead.
IEEE 802.3ae foresees two different physical layers, the so-called LAN physical layer (LAN PHY) and WAN physical layer (WAN PHY). While the LAN PHY represents a pure Ethernet solution operating at 10,0 Gbit/s, the WAN PHY was designed to be SDH friendly. It is important to note, however, that the WAN PHY, operating at 9,29 Gbit/s (corresponding to the payload rate of STM-64c), is not SDH *compliant*: it merely introduces a modified SDH framing, allowing to use SDH access devices such as ADMs (Add Drop Multiplexer), DWDM transponders or optical regenerators; however, it does not support TDM and still uses asynchronous packet transport. The WAN PHY will normally be used to connect the Ethernet device to SDH or DWDM equipment. Especially the option of connecting 10 GbE equipment to a DWDM backbone has large potential.
Contrary to its name, the LAN PHY will not only be used in the local area (e.g. on a campus or server farm) but for long distances as well. The standard calls for a minimum reach of 40 km (using serial transmission over a single-mode fibre at a wavelength of 1550 nm). Equipment providers are likely to offer devices with even better reach, as it is currently the case for 1 GbE, where distances of more than 100 km per hop can be reached without optical regeneration.

New Service Opportunities with GbE

LAN technology pushing into the MAN and WAN certainly drives new business. Numerous Ethernet MAN providers like *Yipes* [4] in North America and *Utfors* [5] in Northern Europe are already well established. They are offering Ethernet connectivity at competitive prices, free

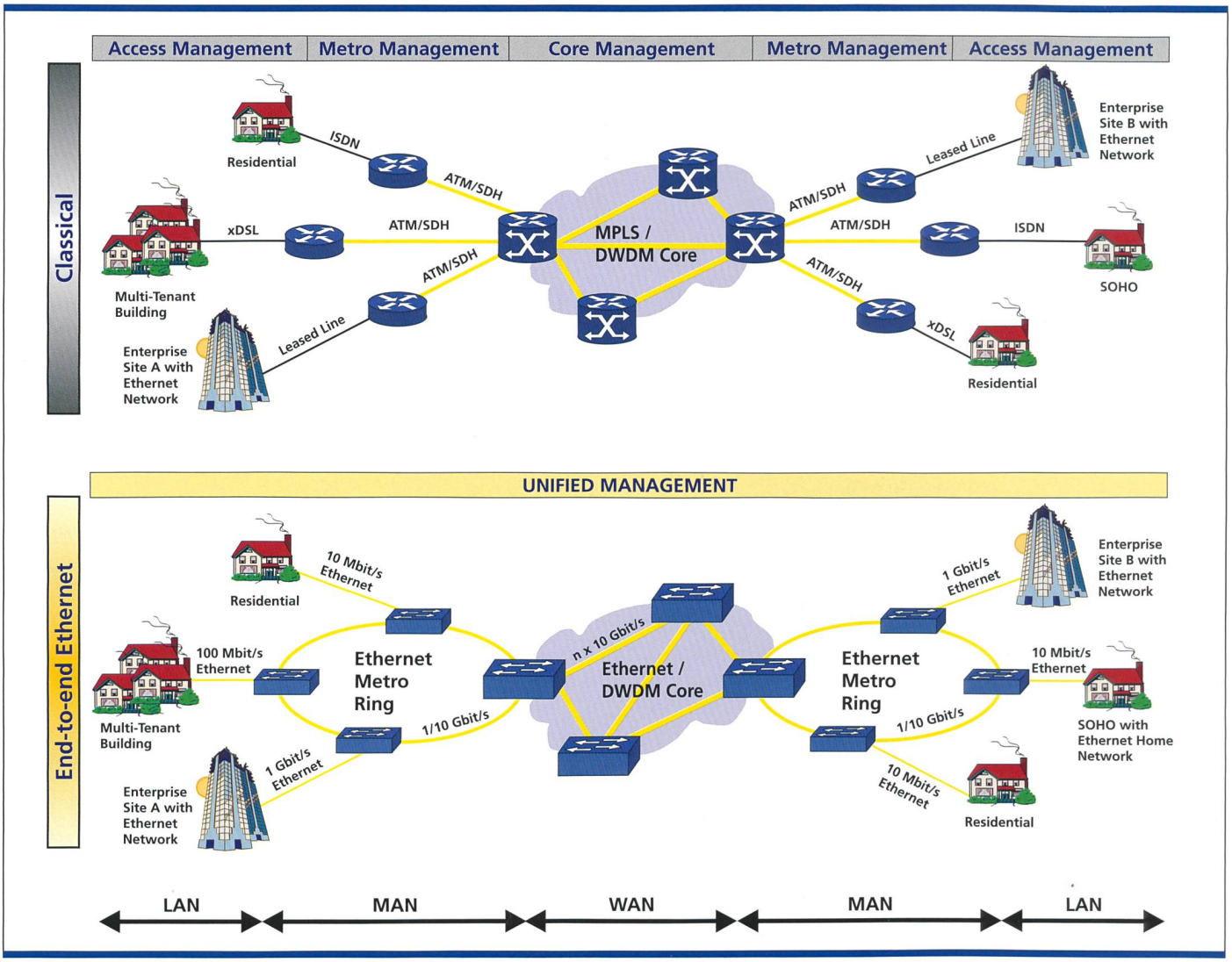

Fig. 5. Classical architecture (top) and Gigabit-Ethernet-based end-to-end solution (bottom).

telephony, VPN and rapid or self-provisioning services. The prices per unit of bandwidth are normally an order of magnitude lower than for leased lines. Besides the regional network providers, there is quite a large variety of applications seen today using GbE:

- Telco MANs including a core backbone, GigaPOP's and server farms
- High-speed LAN interconnection
- Campus backbones
- WAN access
- Internet Exchanges, entirely based on GbE equipment

Standardisation Schedule

The IEEE 802.3ae standardisation schedule is depicted in figure 3. The first draft-compliant 10 GbE equipment is to be released in the second half of 2001. It is believed that 10 GbE will first be deployed in MAN's/WANs. With an increased demand for bandwidth in the local area and a significant price drop, 10 GbE will also appear in LANs. According to the Dell'Oro Group [3], this will not happen before 2003 on a large scale. By 2004, around one million 10 GbE ports are expected to be sold, the majority installed in the WAN and MAN.

Opportunities for Network Operators

The use of 10 GbE obviously allows carriers to enhance their value proposition: reduced operations cost and increasing revenues as a result of new service opportunities should allow to improve the profitability (fig. 4). Moreover, GbE structures can be installed with very short roll-out time (6–18 months) and very competitive capital expenditures, since the pure price of Ethernet equipment is 5–30 times cheaper than for SDH equipment offering the same functionality. According to Dataquest [6], GbE revenues for carriers will grow over 2500% to 1,8 billion US-$ in 2003 for the MAN/WAN, while LAN penetration will significantly take off also in 2003, so that the market will reach 3,6 billion US-$ overall in 2004.

Focusing on Switzerland, the example of Utfors [5] in Scandinavia who has built optical Ethernet rings connecting major cities like Hamburg, Copenhagen, Stockholm and Oslo shows that Swiss carrier networks, whose geographical extent are quite similar, can also be considered as MANs. Therefore, the use of GbE will enable the development of new services at reasonable prices (VPN, Internet connectivity, IP telephony) and thus the penetration rate is expected to grow dramatically in the coming years.

With the steadily rising bandwidth availability, the new generation of metro networks (fig. 5) could indeed be made up mostly by GbE, where ring topologies could be widely deployed. They guarantee both cost reduction thanks to the smaller amount of fibre required, and

higher service availability thanks to their automatic protection switching feature. The aggregation into IP traffic and overall distribution would be carried out towards the core.

Conclusions

10 GbE answers the most recent Internet challenges with an increased bandwidth offering at lower cost. Allowing the carriers to deliver integrated broadband solutions, it drives the revenues for current and future access and Metropolitan Networks. It also pushes the Ethernet into the WAN with the ability to leverage widely deployed legacy systems thanks to SDH-friendly solutions over fibre optics (i.e. it allows to use SDH infrastructure for layer-1 transport only). Bandwidth-consuming applications coming to the fore in the Internet like High Definition TV (HDTV, 10–40 Mbit/s per stream) will perhaps make fibre-to-the-subscriber a reality. In any case, the combination of the advantages of optics and traditional Ethernet allows to deliver high performance data traffic in the MAN. Probably this is the first step towards end-to-end Ethernet solutions.

Outlook

Within its exploration framework Corporate Technology is setting up a fully Ethernet-based LAN/MAN/WAN network infrastructure to experimentally assess the performance and implementation of broadband services. 6

Abbreviations

COPS	Common Open Policy Service
DWDM	Dense Wavelength Division Multiplexing
GbE	Gigabit Ethernet
IEEE	Institute of Electrical and Electronics Engineers
LAN	Local Area Network
MAN	Metropolitan Area Network
MPLS	Multi-Protocol Label Switching
POP	Point of Presence
QoS	Quality of Service
RSVP	Resource Reservation Protocol
SDH	Synchronous Digital Hierarchy
STM	Synchronous Transport Module
TCP/UDP	Transport Control Protocol / User Datagram Protocol
VPN	Virtual Private Network
WAN	Wide Area Network
xDSL	Digital Subscriber Line Technology

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[3] Dell'Oro Group, Ethernet Switches – 10 Gbit/s, www.delloro.com

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Pointers

IEEE 802 Standards Committee: www.ieee802.org/dots.html

IEEE 10 GbE Task Force: www.ieee802.org/3/ae/index.html

IEEE Resilient Packet Ring Working Group: www.ieee802.org/rprsg/index.html

10 GbE Alliance: www.10gea.org

Metro Ethernet Forum: www.metroethernetforum.org

IETF RFC2205: Resource ReSerVation Protocol (RSVP): www.ietf.org/rfc/rfc2205.txt

IETF RFC2748: The COPS (Common Open Policy Service) Protocol: www.ietf.org/rfc/rfc2748.txt

Zusammenfassung

10 Gigabit Ethernet – Eine Alternative zur klassischen MAN/WAN-Technologie

Die Nachfrage nach immer höheren Geschwindigkeiten im Datenverkehr wird durch neue Breitbanddienste wie Video Streaming und die ständig zunehmende Zahl von geschäftlichen und privaten Internet-Benutzern getrieben. Als Antwort auf das Bedürfnis nach mehr Bandbreite im Access-Bereich bietet Gigabit-Ethernet eine massive Leistungserhöhung gegenüber traditionellen, nicht optischen Technologien und passiven optischen Netzwerken (PON). Die tiefen Kosten, der geringe Implementierungsaufwand sowie eine Reichweite von über 100 km machen Gigabit- und 10-Gigabit-Ethernet auch zu einer ernsthaften Konkurrenz zu optischen MAN/WAN-Technologien wie SDH oder ATM. Ethernet ist heute die meistgenutzte Technologie im LAN; sie hat das Potenzial, in Zukunft als Hochleistungsprotokoll im ganzen Netz verwendet zu werden und dabei durchgehende Dienstqualität zu einem vorteilhaften Preis zu ermöglichen.