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Universal Ethernet Telecommunications Service: Towards a new layer 2 based Internet

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Abstract: The Universal Ethernet Telecommunications Service or UETS system reduces the complexity of the Network to an astonishing simplicity. Only two protocols (LLC/ETH) put together in different patterns make, essentially, everything: Ethernet/IEEE 802.3 transports the information, and LLC/IEEE 802.2 performs the control. It is based in the utilization of local MAC addresses, which can be used as hierarchical with topological sense, allowing the physical switching, and the LLC protocol to perform the functions of TCP and UDP protocols in TCP/IP stack. The extreme simplicity of this "ultra broadband technology" allows increasing the bandwidth, reducing the cost and, at the same time, the convergence of voice, data, video, fixed and mobile wireless traffic onto a single network based in Ethernet.

1. Introduction

The UETS Communications Architecture and Reference Model [1, 2] is the natural evolution in Computers and Network convergence: in the 1970s, Systems in Network (SNA/IBM), with proprietary applications in terminals; in the 1980s, Computer Networks (X.25/CCITT), maintaining proprietary applications but in end systems; in the 1990s, Computers in Internet (TCP/IP), with Internet applications; today, in the dawn of XXIst century, the Computer on Net (UETS), with Internet applications. See Figure 1.

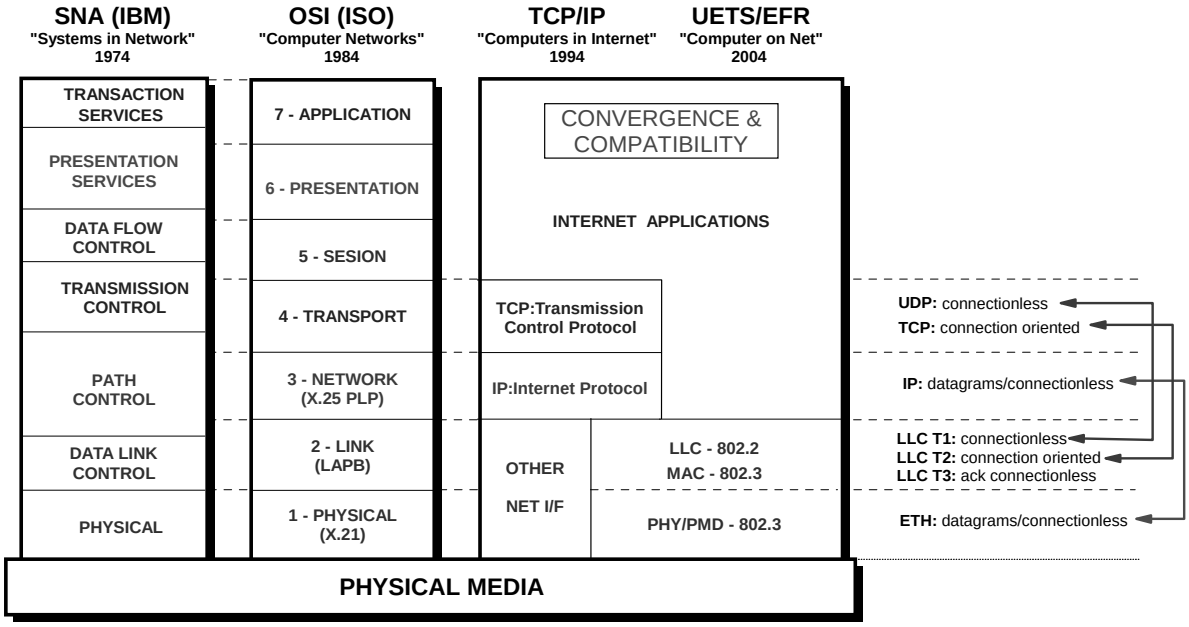

Figure 1. Convergence of Computer and Communications.

2. Objectives

The UETS unified network uses a new generation of devices that makes it possible for Internet applications to operate directly over the link layer defined in the IEEE 802 LLC standard and over the transport layer defined in TCP/IP, with an interface based on Ethernet. The building blocks of the solution proposed are: the applications of Internet, which provides the platforms' independence; the Ethernet and IEEE protocols, which provide the connectivity; and the physical switching of the telephone network, which provides the security and scalability. To develop it, the author has taken advantage of the accumulated experience of more mature technologies: the classic telephone network based on physical circuits, the virtual circuit networks (X.25, Frame Relay and ATM) and datagrams networks (Ethernet Local Area Networks and the Internet-TCP/IP).

This new paradigm drastically reduces the processing overhead: instead of layer 4 (TCP), layer 2 (IEEE 802.2 LLC) would be used for information exchange over the network (Ethernet). Using this technology, the logical and physical networks coincide, while in the TCP/IP reference model the Internet is a logical network (IP) over multiple physical networks (ETH, FRL, ATM, SONET/SDH).

The model has the ability to provide the same services using a layer-2 hardware-based operation device, breaking the limits of hosts collapsed by very-high speed TCP/IP connections [3]. The Logical Link Control (LLC) is better than the TCP/UDP for offering end-to-end services, because it is optimized to hardware operation, and it also has a reduced overhead and a tighter loop control.

3. Technology Description

The IEEE Std 802-2001 defines [4] the use of U/L bit in the 48-bit LAN MAC addresses as follows: "The Universally or Locally administered (U/L) address bit is the bit of octet 0 adjacent to I/G address bit. This bit indicates whether a local or universal administrator has assigned the address. Universally administered addresses have this bit set to 0. If this bit is set to 1, the entire address (i.e., 48 bits) has been locally administered". The other 46 bits can be used, for example, to assign to the switches' port ids to perform the addressing.

UETS is a datagram's connectionless network of Ethernet frames i.e. routing only with no concept of "connections", which are controlled by the LLC protocol outside the network. The local MAC address, used as hierarchical with topological sense, is an alternative to the system of global addressing. A huge deposit that was there, but nobody has seen before. This opens the possibility to do the routing and switching not like IP (at layer 3 with routing tables), 802.1 (at layer 2 with bridging tables), or MPLS (with label swapping), all of them limited by the table sizes and the memory speed [5], but at the physical level, using the bits in the local MAC address to find its destination. The UETS structure, thanks to the use of local MAC addresses, is similar in some way to the telephone numbering plan: different segments of the address are used at different layers in the switching hierarchy. See Figure 2.

The UETS/EFR architecture provides inherent security: the MAC addresses, given that they are a direct binding to the network access point, can not be spoofed. Also, physical access to the point of attachment is required for supplantation, because the domain administrator controls them. Being a layer 2 network, this security may be complemented with 802.1X, no attacks based on manipulation of the spanning tree protocol are possible, and there is no spanning tree protocol (the switches do not learn addresses) in the UETS network.

UETS switch fabric can be implemented by Banyan networks, the less complex and most scalable interconnection topology. As a reference, while fastest routers has 600 Gbps switching capacity per chassis (90 Tbps the router), it has been demonstrated switching

capacities in the range of 10-50 Tbps in a single chassis using a commercial Banyan switches. It means 100 times more speed and a cost far below.

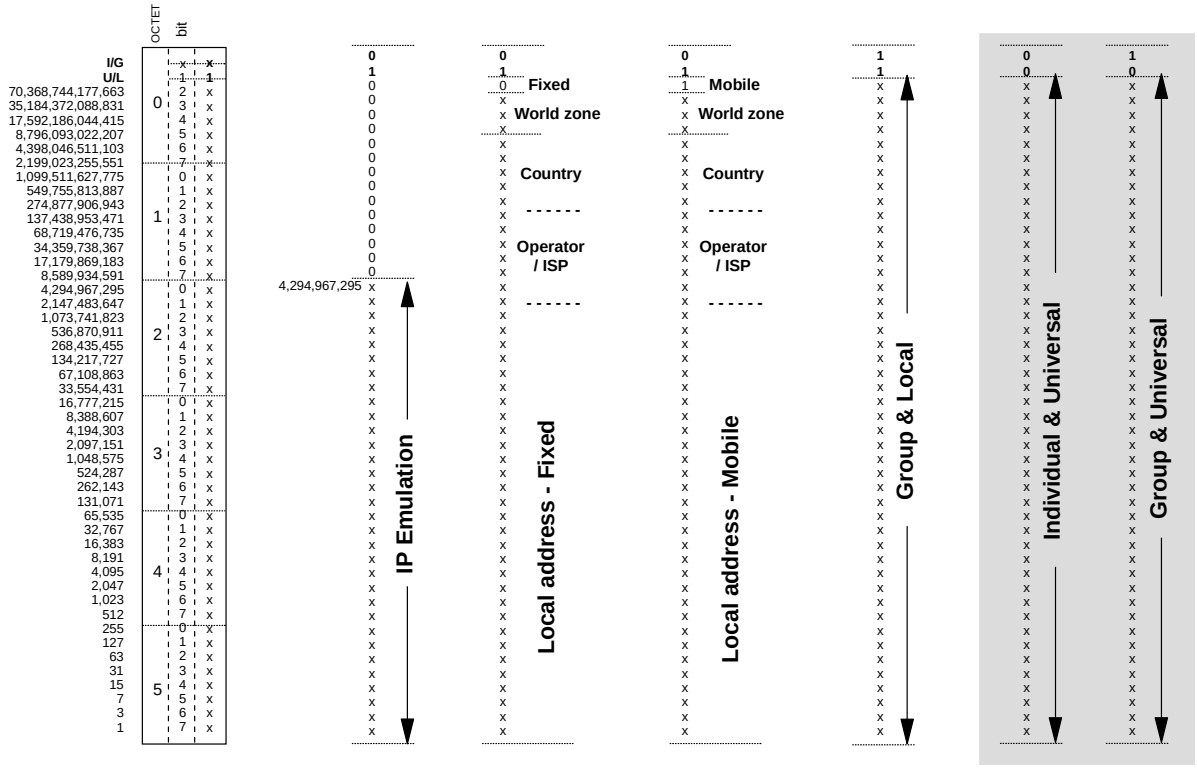

Figure 2. MAC Address Administration. Example.

The XXIst century network should be "quadruple play": data, voice, video and mobility. Using UETS' Ethernet local addresses instead of IP in the 4th generation, and the techniques used today with telephone numbers, it is possible the fixed and mobile terminals convergence. The fixed and mobile terminals can be discriminated by one bit, as described in Figure 3. If the terminal is fixed, the address is used directly to perform the switching, if mobile, the address should be associated with a fixed one by the Base Station.

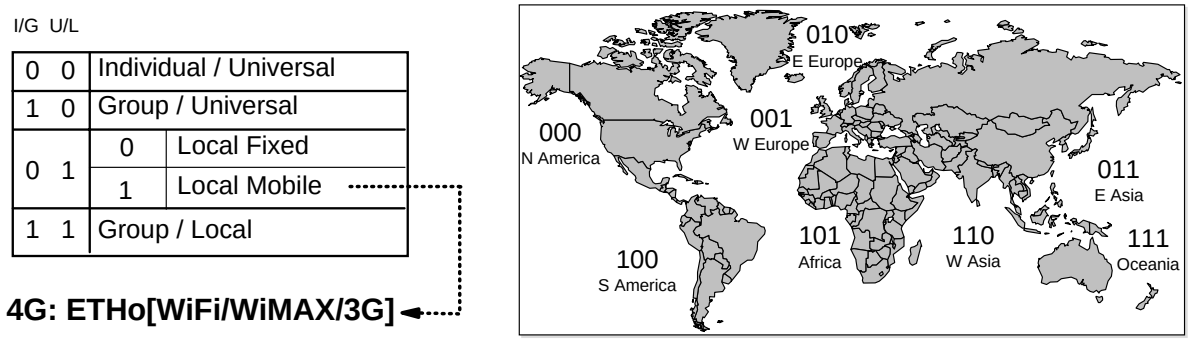

Figure 3. Fixed/Mobile and World Zones bits. Example.

With an efficient structure, only one UETS domain provide for very big number of connections. According the example of Figure 4, Spain will have 549,755,813,887 fixed, 549,755,813,887 mobile and 1,099,511,627,775 group (multicast) addresses. In addition, using MAC-in-MAC, each connection will have another Ethernet domain, with an addressing structure similar to IPv6.

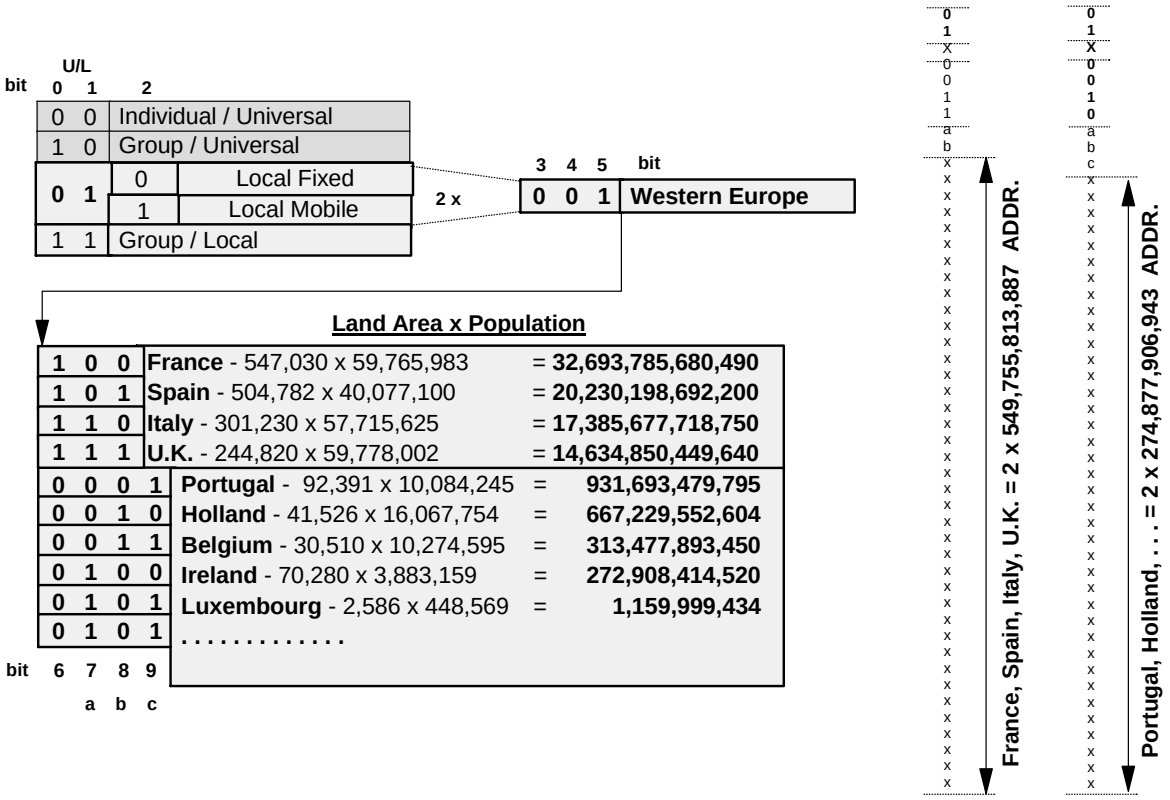

Figure 4. Address Distribution - Western Europe. Example.

There's only one value in MAC address for each terminal's I/F in the whole domain, independent of the source. In a fixed hierarchy, the switching nodes know which of the bits of the address it needs looking at the MAC net mask, as described in Figure 5.

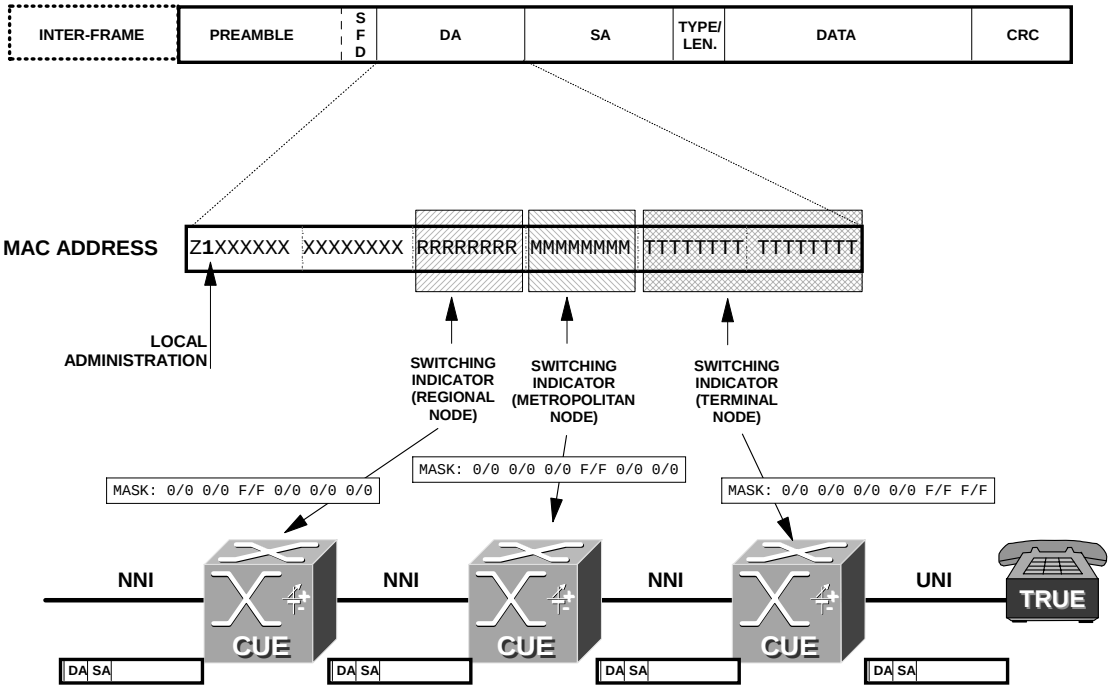

Figure 5. Switching indication. Example.

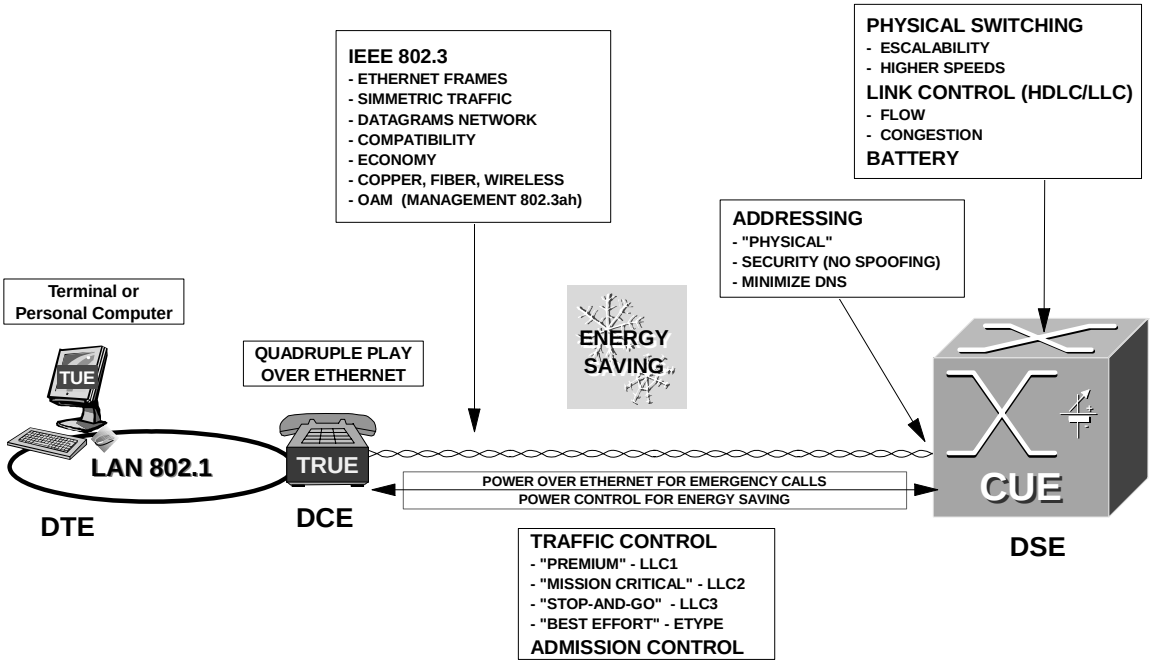

Figure 6. UETS Service: Network Elements.

3.1 – Ethernet Domain extension to service providers' network: From LAN to UETS.

The "Local Area Network" or LAN is defined in the IEEE standard STD 802-2001 as "A computer network, located on a user's premises, within a limited geographical area". Therefore, the Classical Local Area Networks limits the Ethernet domain to building/campus. An essential point for the UETS is to extend the local Ethernet network to include the public carrier's network. The building blocks are described in Figure 6.

3.2 – New access device: "TRUE" (TerminatoR of Universal Ethernet network)

In addition to the basic telephony service, users can connect terminals of diverse types through a Local Area Network to the TRUE, the network termination equipment. Thus, terminals can have access to the UETS network in order to use any of its services. This is an advanced demarcation device that is connected via the UNI (User Network Interface), which performs the traffic, admission and congestion control, enabling an intelligent service to offer real time applications such as voice and video over packets (IP or Ethernet).

3.3 – New terminal concept: "TUE" (Terminal Universal Ethernet)

The Internet applications provide the platforms' independence. The dual protocol stack allows communication with remote systems over Ethernet using the sockets for LLC or TCP/IP. The UETS terminal use in Ethernet domain IEEE 802.2 LLC protocols, and in IP domain UDP and TCP protocols. At the same time, collaborate with the UETS Central Offices in network congestion control, because both supports layer 2 LLC protocol, allowing service differentiation and QoS:

- LLC-1 "premium" services (rt-CBR / rt-VBR)
- LLC-2: "MISSION CRITICAL" services (nrt-VBR)
- LLC-3: "STOP AND GO" services (HDX, BSC type)
- ETYPE: "BEST EFFORT" services (TCP/IP)

3.4 – New network node concept: Central Office "CUE" (Central Universal Ethernet)

The network nodes will be in charge of the service connections and the Ethernet frame switching at the physical layer, based on the local MAC address [6]. The combined operation of the CUE and the UETS terminals open the possibility to do the network flow control and congestion management. The applications and addressing are based in the Internet IP mechanisms (with the 6 octets MAC instead of the 4 octets in IPv4), while the switching is, basically, similar to central offices based in the old "hardware" telephone switches (like rotary or crossbar) philosophy, but operating in datagrams packet mode. The destination MAC address represents the intended destination, but not the path: the switches find the destination step by step, but based in pure hardware. This process is performed in UETS/EFR frame by frame, using Ethernet switches, without switching tables or label stacking. Like in Internet and in the telephone network, it is required to know the "address/number" of the destination or find it in a directory, here called the EDNS (Ethernet DNS), similar to IP DNS, but with 6 octets addresses. The hierarchical structure of UETS addressing/numbering makes possible to reduce drastically the EDNS usage.

All the switches use the mask to know which bits of the MAC address to look at to switch the frame. In the border nodes, if the destination is the same switch, deliver the frame to the destination directly over the UNI. In other case, performs a "micro routing" to the higher level node to deliver the frame over NNI. This mechanism offers a high level of resilience to the network. The higher layer nodes makes the same thing with its mask, but they doesn't have UNIs, therefore they have to decide if to reach the destination they have to deliver the frame to an upper or lower level switch.

3.5 – Integrated power management system, for energy saving

The current Ethernet terminals consume power all the time, while in UETS there is not powered when they are not in use. This feature, applied worldwide, will save in 2010 the equivalent to 40 central baseload power plants [7]. Remote powering via the twisted pair from the central office allows the emergency calls service, guaranteed by means of batteries. The connection complies with the conditions of the classic telephone network to be a telecommunications service, guaranteeing the emergency call service (112 in the EU).

3.6 – Security

UETS architecture solves Ethernet's scalability and security problems: MAC addresses are physically dependent and controlled by the ISP or network owner, allowing hardware based switching and enhancing network security by preventing layer two address spoofing. Each TUE will be able to work on the secure zone of the Ethernet domain and use, without risk, the resources offered by the UETS network servers: applications, data, audio, video, control, etc. Additionally, the L2 connections do not have the risks related with IP protocol.

4. Business Benefits

The convergence in the Information and Communications Technologies requires removing the complexity of current technology, and simplifying the ever growing number of equipment and network technologies. The UETS/EFR architecture would take advantage of this concept, because it follows the "Ethernet paradigm shift", and "having a small number of networks is better than a large number of networks". It could be applied to High Speed Networks (LAN/MAN/WAN), Storage Networks (SAN/NAS), High Performance Computing (HPC), Networks of Workstations (NOW), Layer 2 VPNs, Video HDTV distribution, Home Networking, Secure Networks and many others, i.e.:

4.1 – Carriers and Network Operators Ethernet's Services

UETS has been described as "Connectionless Provider Backbone Transport", using MAC-in-MAC encapsulation (SNAP or 802.1ah, with VLAN tags) to handle customer traffic transparently, carrying the universal addressed Ethernet (802.1 in LANs) over the local addressed Ethernet network (UETS in MAN/WAN). The core nodes only care about switching traffic and do not have to care about the users' MAC addresses. In this case, the addressing will be huge, even bigger than IPv6. This system turns off "broadcast unknown" and "bridge learning", providing speed and addressing scalability, inherent security, real time traffic support, multipoint-to-multipoint and multicast services. Today, the solutions defined by IEEE 802.1, MEF and ITU-T only support point-to-point and point-to-multipoint services, using switching tables or label swapping techniques, an the classical DTE addressing, described in Figure 7 (a) and (b).

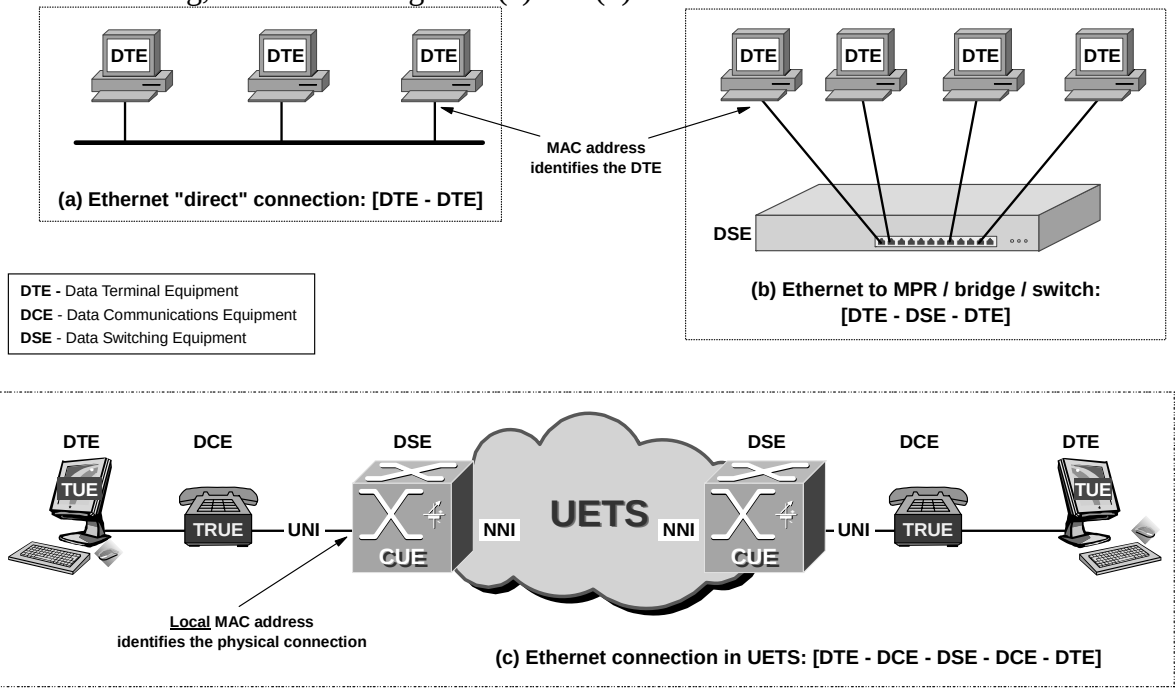

Figure 7. Ethernet/IEEE 802.1 vs. UETS: a true telecoms service.

Many people have found it hard to understand the meaning of "local MAC addresses fixed by the physical address of the network node", described in Figure 7(c), which makes UETS a true telecommunications service.

4.2 – Storage Area Networks (SAN) and Multi-Processor Systems

This proposal shares with Fibre Channel the "Fabric Routing" and "Link Layer Control." It provides interconnect systems for multiple topologies that has proved its ability to deliver a high level of reliability, availability, security and both scalable throughput and capacity. The LLC protocol carry out the functions performed by TCP and UDP in TCP/IP stack, and the double stack maintain full compatibility with IP. The LLC is hardware oriented, having the capability to perform the flow control and congestion management. The most successful fabrics share the UETS characteristics: physical level switching and link layer control [8].

4.3 – High Definition TV Distribution

The telecoms industry needs a solution to the convergence between content providers and network operators. Today IPTV technology isn't ready yet for deployment on a mass scale, and High Definition needs more bandwidth. The solution proposed here meets the demands

of the Next Generation Network, providing the future proofed infrastructure to deliver economical, flexible and intelligent broadband services. This kind of traffic is supported by the LLC-1 protocol, which guarantees the needed performance because it does not have queues or buffers. Working in connectionless mode, it is not affected by the latency-bandwidth trade-off in gigabit networks [9].

5. Conclusions

The UETS/EFR is an extremely simple an efficient network technology, which performs physical switching with minimum protocol overhead, at very high speed with low latency. The exclusive use of Ethernet simplifies the net and support real time and mobile services convergence, profitable for carriers and affordable for customers. Users can access their data or services inside the Ethernet domain in a more efficient and secure way, but at the same time, there is full connectivity to the IP domain, to access the universe of Internet services. It means total compatibility and scalability without disruption. This technology corresponds to the link layer, which supports any kind of network —it is "per se" multiprotocol—, and is an ideal media to connect terminals throughout a single network (net) and not via a set of interconnected networks (internet). Ethernet can offer link (Layer 2 LLC) and network (Layer 3 IP) services, while IPv4 and IPv6 offer exclusively network services or tunnels. With UETS system, as opposed to what happens with IP version 4 and 6, it is unnecessary to migrate from the current Internet over TCP/IP, since the two technologies can harmoniously coexist.

EU Information Society Commissioner Viviane Reding said: "it is worrying that in ICT research, Europe continues to lag behind its competitors, investing about half as much as the US. Only through stronger investment in ICT research and effective cross-border competition will we ensure that the great potential of ICT is used to lift our competitive performance across the economy." UETS/EFR is a proposal with a potential that fulfils these objectives. As a summary, this is a radical new way to proceed. Is these kind of ideas that increase the speed by an order and decrease the price by two orders.

We already have the model, the skilled people and the knowledge to implement it. What we just need is the political ambition to create lobby and public support. Not allowing what in the future might be remembered as the third time that Europe missed the opportunity to lead the internet revolution: first was with Donald Davies (National Physics Lab, UK), when his pioneering ideas of Packet Switching (foundations of the internet technology) were dismissed, or (second) when Tim Berners-Lee's (CERN, CH) was almost forced to move out from Europe in order to keep the web developments working.

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