# Universal Ethernet Telecommunications Service: A new Communications Architecture and Switching Paradigms


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# Universal Ethernet Telecommunications Service: A new Communications Architecture and Switching Paradigms

**José Morales Barroso, L&M Data Communications**

jmb@ieee.org



The Universal Ethernet Telecommunications Service (UETS), is an Ethernet based datagrams network that combines the advantage of circuits, the flexibility of datagrams, the resilience of routing, the "physical" speed and scalability of ATM switches, and the control capabilities of HDLC/LLC protocol. The new switching technique proposed here is called the Ethernet Fabric Routing (EFR), because the routing process is performed by the network own nodes' switching fabric, using Ethernet local MAC addresses (U/L bit = 1) that can be topologically related. In that case, the nodes route the frames to its termination based only on the Destination MAC address. This technique is characterized by its simplicity (it does not need bridging, routing, look-up or signaling tables), its performance (only dependent of the fabric hardware,) and its inherent security.  The terminal does not use its own universal address, as in conventional LANs, but the switch's port physical address, as it happens in the old telephone Central Offices.

To switch the Ethernet frames, the communication nodes use the local MAC addresses as implicit labels with global, not local, meaning. The switching equipment can also make use of built-in routing "micro tables" with the highest order bits of the label (MAC address), to offer a resilience in the network core. At the same time, to control the end-to-end connections, UETS network interface in the Ethernet domain comes to be at layer two (link) with the IEEE 802 LLC protocols, which belong to the HDLC family. To communicate over IP internets, it uses the layer four (transport) with the TCP/IP stack. Therefore, UETS Network doesn't compete with TCP/IP, but complements it. The new node concept, Central Universal Ethernet (CUE), makes possible building bigger and faster network nodes, which will interact closely with terminals to perform flow and congestion control in collaboration, thanks to LLC protocol control capabilities.

# The UETS System

The first and primary concept of UETS is a set of enhancements to Ethernet switching architecture for an Ethernet-only network [1], which integrates and delivers all the digital services.

Multiple carriers, equipment vendors and Standards Committees, like IEEE 802.1 or IETF, are considering a similar concept, but the solution proposed here is radically different to all of them. Nowadays, everyone agrees that the network must be "everything IP", to support Internet applications with TCP/IP protocol stack, and the Ethernet devices must use the universal address (bit U/L=0). There is no reason to build the network exclusively at the transport layer (TCP/UDP) to run Internet applications, or use an anarchical (universal) addressing in the Ethernet domains. What the applications need is a datagram network, like IP, but also Ethernet, and a protocol to send the packets end to end: TCP/UDP when we use an IP internet, or LLC over a single Ethernet network.



With only one Ethernet network and local MAC addresses, it is possible to build a schema like the POTS, being the address fixed by the node's port, like in the old Central Offices. This strategy permits to switch Ethernet frames directly at the physical layer, making it unnecessary to use routing, bridging, or signaling techniques. The Destination Address has the routing information, and does not need the use of switching, look-up or forwarding tables. With 46 bits available in the address field, the network can have more than 70 trillion terminals in unicast mode, and the same number can be used for multicast addresses. Using the VLAN tags and MAC-in-MAC encapsulation the addressing space can be increased. In this case, we would have up to 106 bits, or 81,129,638,414,606,681,695,789,005,144,064 different addresses.

This solution makes UETS an ideal system: a network capable of offering universal support through a single addressing scheme, a single framing system, a single type of switch on the physical layer, a single data congestion and flow control, and the ability to connect through any type of physical media. And all this using a single standard: Ethernet.

# Background

The UETS design has taken advantage of the accumulated experience of more mature technologies: the classical telephone network, based on physical circuits (POTS), virtual circuit networks (X.25, Frame Relay and ATM), IBM's System Network Architecture (SNA), IEEE 802 Local Area Networks, and the Internet TCP/IP.

The Internet is based in the *catenet* concept, as Vint Cerf describes it in the IEN48 document, a "confederation of cooperating nets." He developed TCP/IP "to interconnect these networks in such a way [...] that would allow many such networks to interwork and the computers on each of them to interwork." This allows the existence of a unique logical network over the many physical networks it was necessary to interconnect. The intelligence resides in the host (TCP), at the edges of the datagrams network, leaving the nodes (gateway/routers IP) working only in communication tasks. This model is much more scalable and efficient than the virtual circuits of X.25, Frame Relay or ATM, being this one of the keys of Internet success.

Another key of the Internet success is the *socket*, which permits the evolution from the classic "*computer network*" to the "*computer on net*" model [2]. Internet is the equivalent to a single computer in which the resources are distributed and accessible from any location. We must consider this as a basic reference model, and it has to be maintained. Figure 1 describes the "classical catenet" concept with the TCP/IP stack, in which the communication between hosts are performed with software at the layers 3 and 4.

This model doesn't support real time traffic, and, according to Steven Cherry, IEEE Spectrum's Senior Editor, "If there's a next killer application for the [...] telecommunications industry, it's the triple play of voice, video, and data. [...] However, voice and video services are very different from broadband data. [...] How, then, can carriers deliver these time-critical applications across the Internet?" [3].

The proposed solution, the UETS network, is capable of carrying IP traffic, maintaining full compatibility with the current Internet and its applications. but in order to improve its capabilities, the model uses a double protocol stack over Ethernet frames. Besides the "classical" TCP/IP, in the new one the sockets, that are intact in the application part, use LLC2 instead of TCP, and LLC1 or LLC3 instead of UDP. Figure 1 also describes the “new catenet” concept applied to the UETS model with the LLC/ETH stack. The communication between applications can be performed with **hardware** at the layers 1 and 2, making possible to increase the speed, and control the communication through the cooperation of hosts and network nodes.

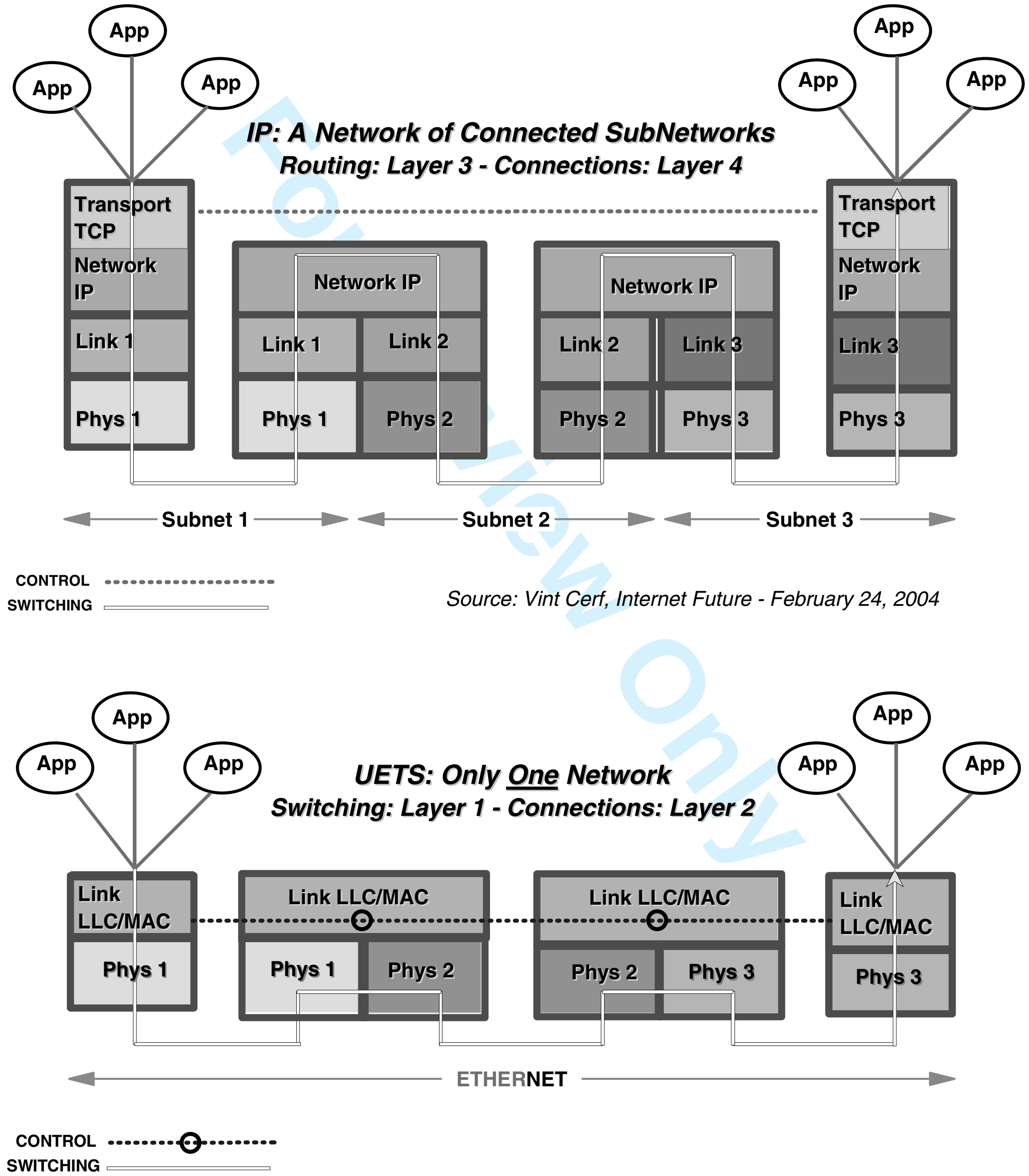




**Figure 1 .** *Internet: "Interconnected Networks." vs. UETS: "Only ONE Network".*

# Communications Architecture

One of the fundamental principles of the system is based on the fact that Internet applications now use the TCP/IP protocol stack, which corresponds to layers 3 and 4 of the Architecture of Reference. The existing technology makes possible that these operate directly on the link layer as defined in the standard IEEE 802, a solution to the unified network that offers UETS.

The communications architecture of UETS follows the IEEE 802 LAN&MAN Reference Model for end stations, as described in IEEE 802 [4]. Those services can operate over the MAC SAP offered by Ethernet IEEE 802.3 **unacknowledged connectionless-mode** networks.

The Reference Model for TCP/IP offers two types of operation for data communication between transport service access points: **unacknowledged connectionless-mode** (UDP) and **connection-mode** (TCP) over the internet service access point offered by the Internet Protocol (IP) in **unacknowledged connectionless-mode**.

If TCP/IP services are offered over an Ethernet network that follows 802 RM, there is a double redundancy. The connectivity services offered for the transport layer over TCP/UDP are equivalent to those offered by the link layer over LLC, and the datagrams' services offered by IP are equivalent to those offered by Ethernet.

A logical network (IP) composes Internet TCP/IP over multiple **physical** networks (ETH, FRL, ATM, and SONET/SDH). In the “Inthernet” of UETS, the **logical and physical** networks coincide. The use of Ethernet also offers seamless interoperability and adaptation to changing requirements. Ethernet and IP share a set of characteristics of fundamental importance. Both are packet based, a technology designed for computer communications which provides statistical multiplexing, which is needed for the economic sharing of network resources. Also, it operates in connectionless-mode, fundamentally more reliable and scalable than the connected-mode. In brief, the services provided by IP in an internet are the same that the services provided by Ethernet in one network.

There are clear advantages to “collapse” TCP/IP to LLC/MAC, as described in Figure 2. It will give us the ability to provide all the services at Layer 2, and do it all on a common infrastructure. As a matter of fact, TCP/IP hosts do not use the logical IP addresses in Ethernet domains, they use the physical MAC addresses, which are obtained by means of ARP.

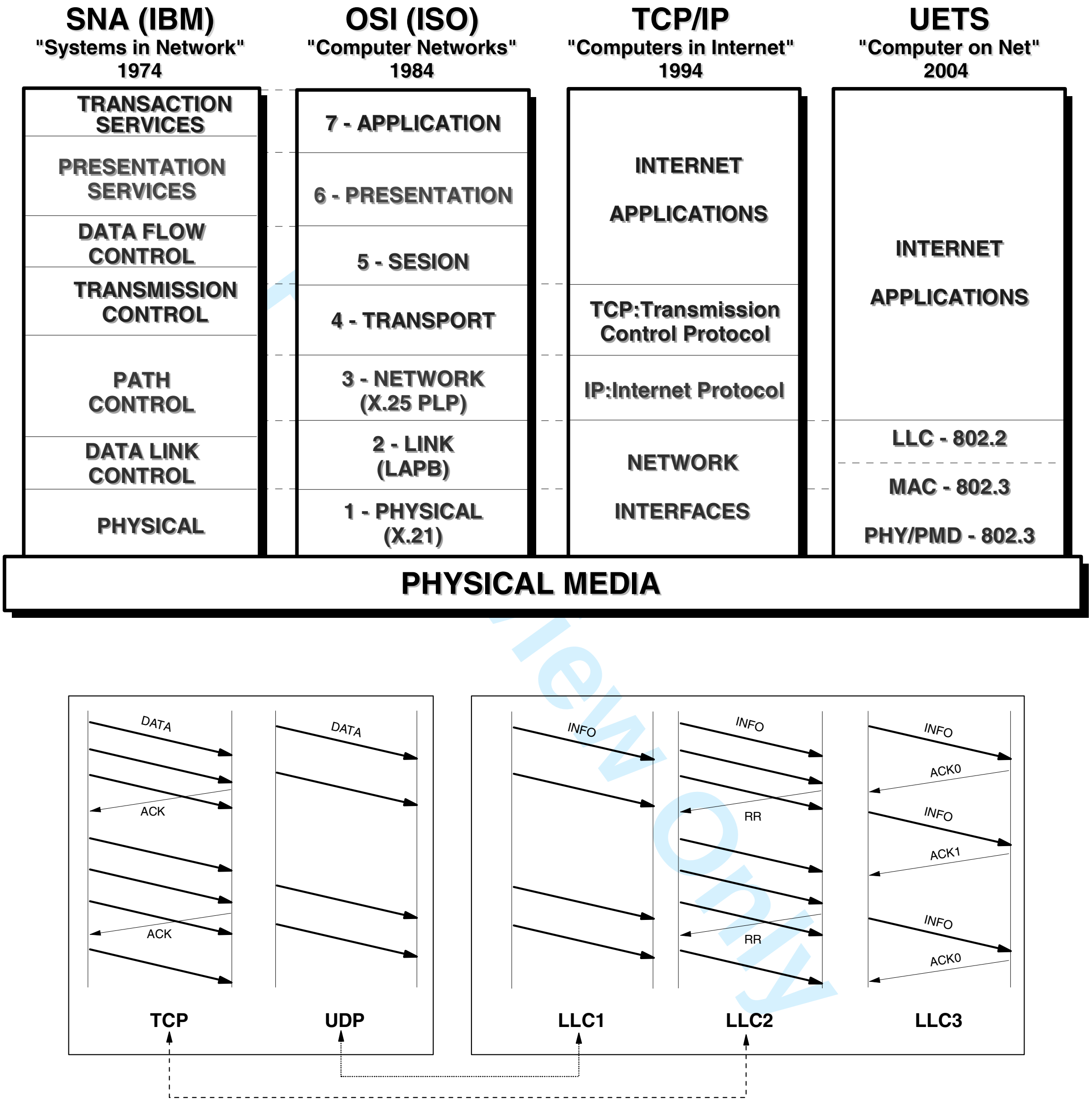


**Figure 2 .** *UETS Communications Architecture: TCP - UDP vs LLC Types.*

The LLC is a bit oriented protocol, member of the HDLC family, which is used in many communication networks: SDLC/IBM, LAPB/X.25, LAPD/ISDN, LAPF/FRL, and PPP/IETF. LLC is always better than TCP/UDP at offering the end-to-end services since it is optimized for hardware operation, having also a reduced overhead and a tighter loop control. However, being a link protocol, LLC is required to operate over a network that does the switching at the physical layer, as UETS do.

This radical new approach maintains untouched the original idea and "The Spirit of the Internet." It works like the plain old telephone network, but in packet mode with Ethernet frames, while maintaining the Internet applications, using for the communication either the TCP/IP or the IEEE 802.2 protocols, and eliminating the characteristic insecurity of the IP protocol when the communication is established within the Ethernet domain. In current IP environments, with 802.1 bridges and universal MAC addresses, an attacker can spoof MAC addresses. In UETS, the use of the **local MAC addresses fixed by the physical address of the network node** makes impossible to falsify them. In this way, we can consider UETS connections as a Virtual Private Network.

The IEEE 802.2 standard, specified in 802.3 for sublayer 2, offers a datagram service with LLC type 1, a connection oriented service with LLC type 2, and an acknowledged connectionless service with LLC type 3 that can be useful in some applications, like IPC (Inter Process Communications.) There is another advantage in using LLC; it is a Balanced protocol, while TCP is Unbalanced (client/server.)

This is a hardware oriented protocol: introduces minimum latency, will operate at very high speed, 10 Gbps and more, like routers with PoS/PPP, and is very efficient, because it is a HDLC protocol with very low overhead. In addition, it offers link layer error free guaranteed delivery. To offer the full services described in UETS, the HDLC option 3 (Selective Frame Reject) must be added, and a frame format that performs the PAUSE function must be defined.



## 802 / 802.3 MAC Administration

The IEEE Std 802-2001 describes in its paragraph 9.2 [5] the utilization of bit U/L 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 the 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."

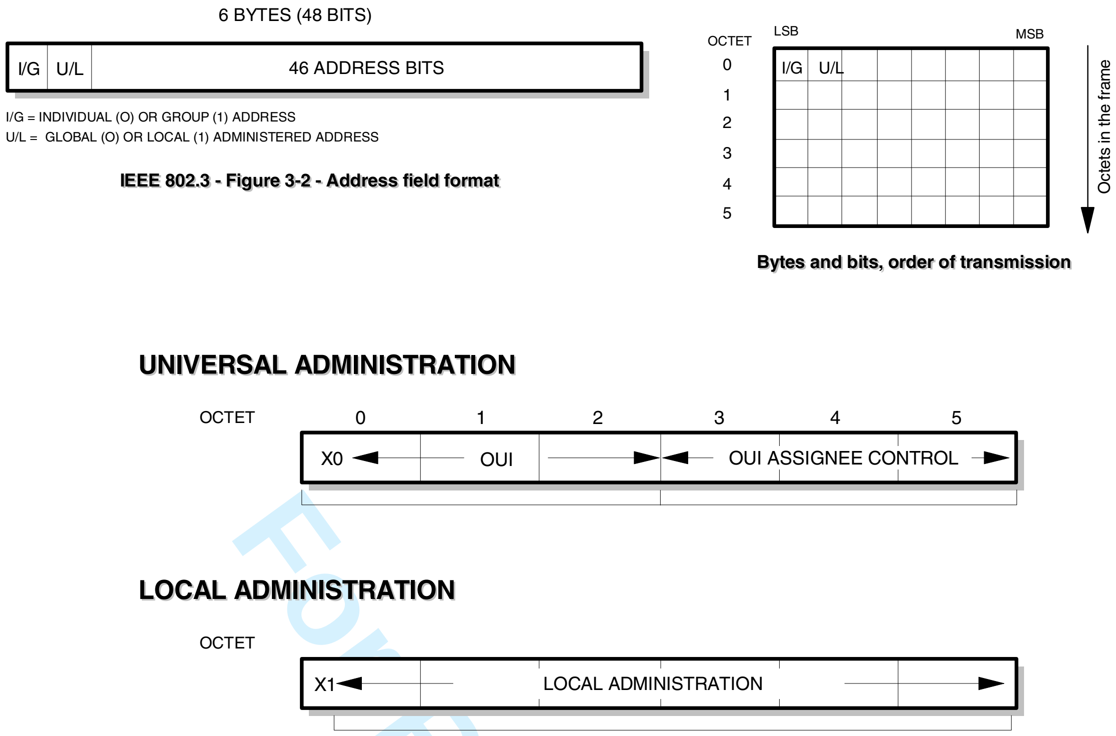


**Figure 3 .** *MAC IEEE 802/802.3 - Address field format and administration.*



The IEEE Std 802.3, as described in Figure 3, defines the use of MAC addresses in Ethernet environments [6]: "Each MAC frame shall contain two address fields: The Destination Address field shall specify the destination addressee(s) for which the frame is intended. The Source Address field shall identify the station from which the frame was initiated. Each address field shall be 48 bits in length. The first bit (LSB) shall be used in the Destination Address field as an address type designation bit to identify the Destination Address either as an individual or as a group address. In the Source Address field, the first bit is reserved and set to 0. The second bit distinguishes between locally or globally administered addresses. For globally administered (or U, universal) addresses, the bit is set to 0. If an address is to be assigned locally, this bit shall be set to 1. Note that for the broadcast address, this bit is also a 1."

# Switching Architecture

In the current public telecommunications network, many different technologies co-exist: optical with analog WDM circuits, pure TDM for the SONET/SDH transmission network, POTS circuits for voice, virtual circuits for ATM, datagrams for IP, and MPLS in the core. To use a single technology in the entire network would be extremely useful, and this is what Ethernet with the UETS model provides. The network nodes of UETS are called CUE (Central Universal Ethernet,) because of their analogies with the classic telephone Central Offices.

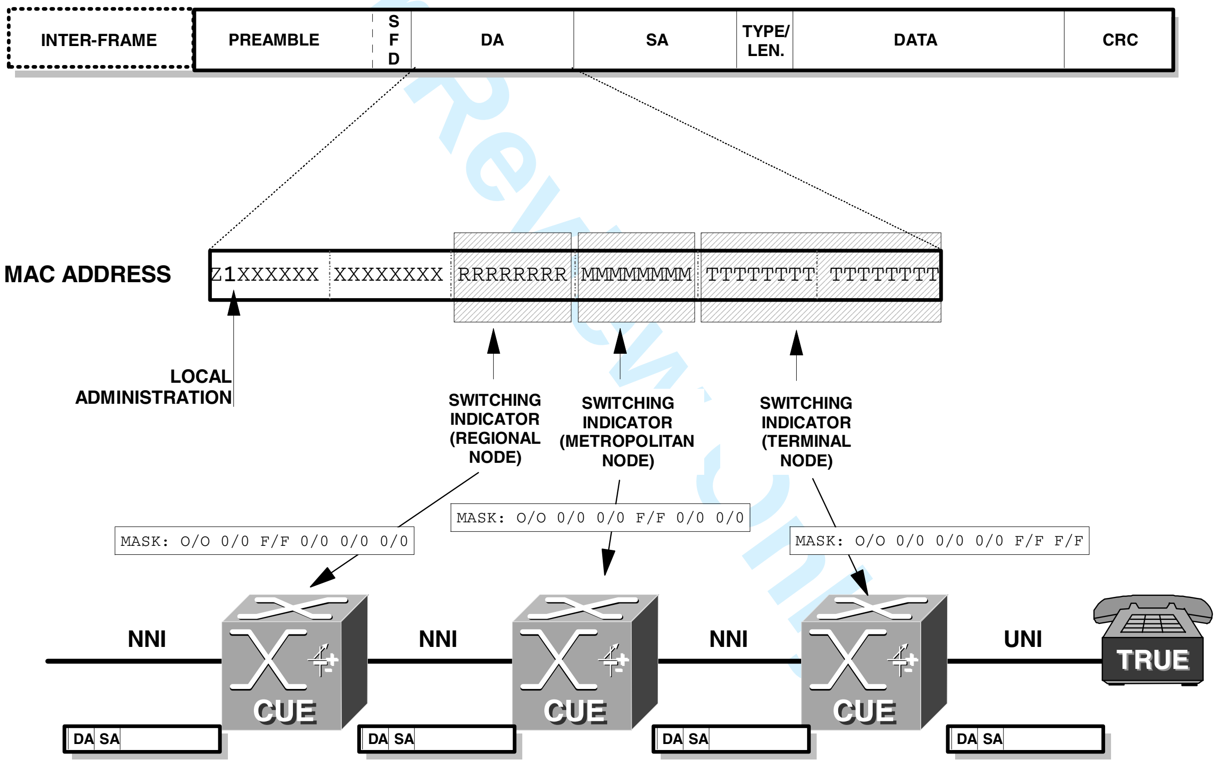


**Figure 4 .** *Switching indication. Example.*

The Ethernet frames can be routed in the core by means of, for example, the switching fabric of ATM/MPLS equipment, using as label the part of the local MAC address that corresponds to the addressing range of the node, as described in Figure 4. This technique does not need the "label swapping" performed in ATM/MPLS; the switch fabric does not change the MAC address, progressing it without changes to its destination. Also, to construct the address, the Terminal Node CUE, that has terminals connected directly, will inherit the switching indicators from the CUEs of higher levels (Metropolitan, Regional, National, and International.) This mechanism preserves the customers' Ethernet frames through the WAN, making the switching process extremely simple and transparent end-to-end.

In the ATM's switch implementation, the ATM physical address identifies the physical port, and the VP/VC pair the virtual circuit identifier. In order to do the switching, an association of input VPi/VCi and input port is needed, with the output VPo/VCo and output port in the switching table. This is made by the signaling protocol. The node has to change the VP/VC pair and switch the cell from the input to the output ports.

The CUE network nodes switch Ethernet frames at the physical layer. This means packet-mode transmission with circuit characteristics. To do this, it uses the **local MAC** addresses, which can be organized to make **the bits in the address** the same that **the physical address of each port**. It is something similar to the operation of the classical telephone network: the telephone number is fixed by the central office, and can't be changed by the end user.

The attributes that make this system different are 802.3 frame switching at the physical layer, allowing for very high speeds and the capacity to carry out error correction, plus flow and congestion control with the collaboration of the terminals by means of the LLC protocol. This is possible by using layer 2 protocols to communicate the terminals on the UETS domain. With TCP transport, IP routers cannot participate in the error and congestion control. This has to be made by the terminals with the Slow Start, Congestion Avoidance, Fast Retransmit and Fast Recovery procedures. These are fundamentally important to support congestion management over a geographical network like Internet today. In UETS, those procedures are performed by the LLC protocol, at link layer instead of at transport layer. In addition, the Congestion Control performed by means of the LLC protocol in cooperation between terminals and network nodes, makes possible to turn Ethernet's service into deterministic and guaranteed. The use of hardware-based forwarding improves performance and reliability, and makes possible to scale the bandwidth and the total throughput of the switch in packets per second.

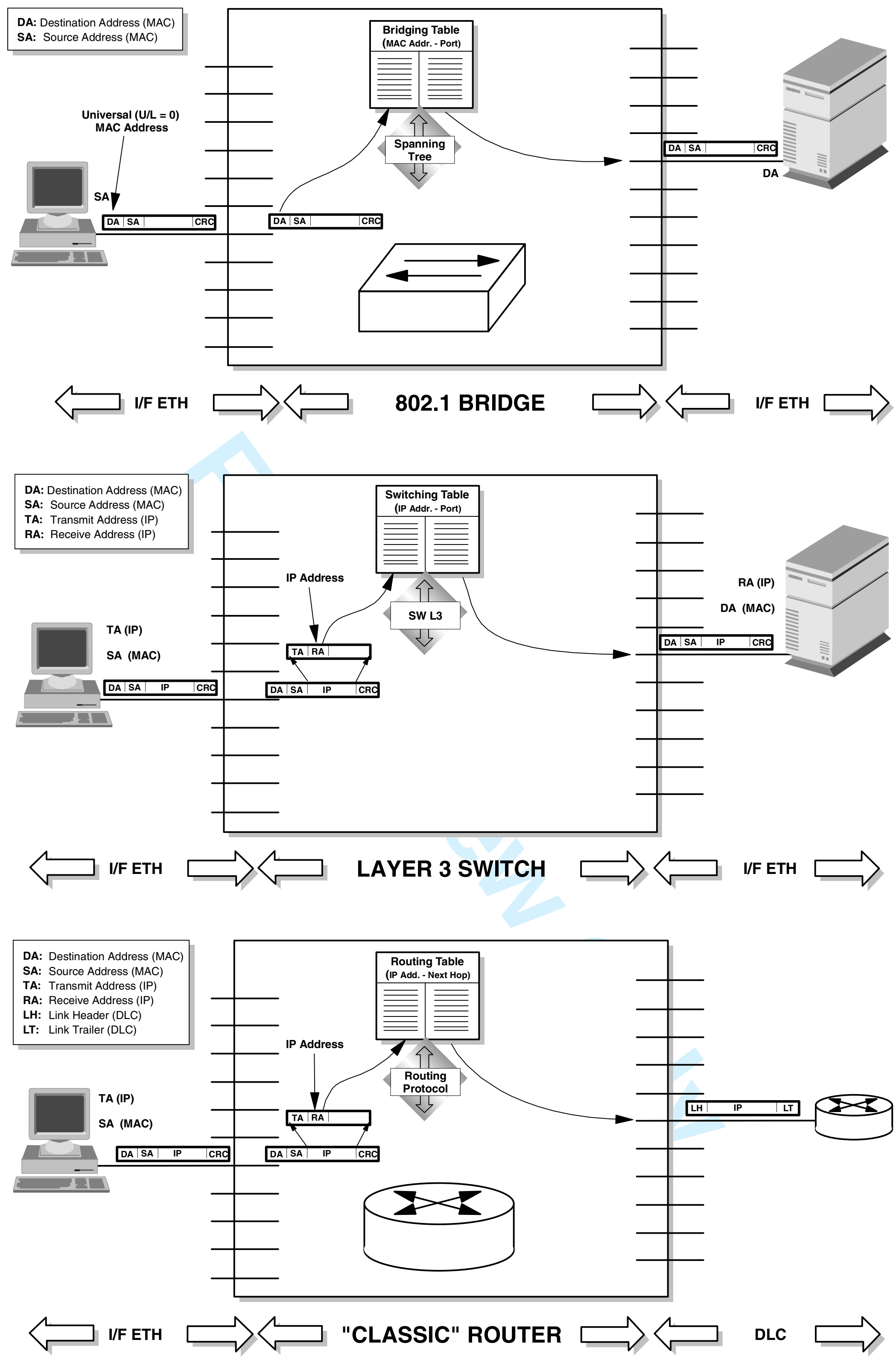


**Figure 5 .** *802.1 Bridge; Layer 3 switch, and Router implementations.*

The simplicity of the CUE draws a distinction with the inherent complexity of 802.1 bridges, Layer 3 switches and IP routers (Figure 5). Bridges and switches limit the scalability because they use universal MAC addresses, allocated to manufacturers, being the routing tables for such a systems extremely large and sparse. At the same time Routers limit the speed of IP networks because they work at Layer 3. This difference can be seen in Figure 6.

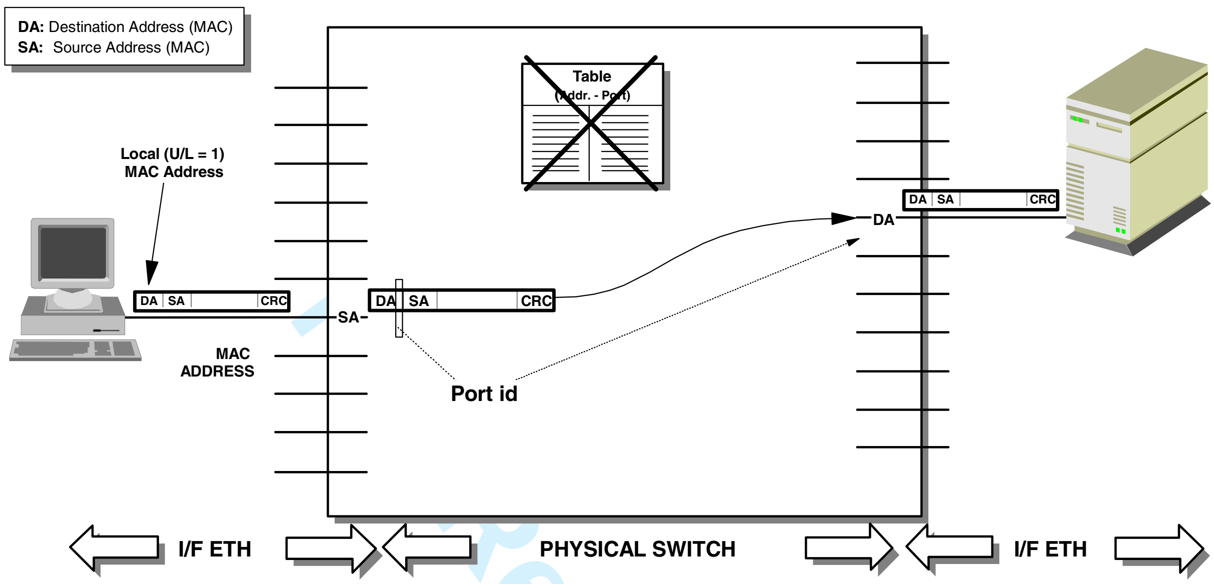


**Figure 6 .** *CUE implementation from bridge, L3 switch or IP Router fabric.*



## TRUE: The Access Device

The access to the network is allowed using the “TRUE” (TerminatoR of Universal Ethernet network), a device powered from the Central Office when connected to the telephone twisted pair of the subscriber loop, or from whatever other physical means whenever it is necessary (copper, fiber or wireless). The principal elements of the TRUE device are quite similar to those of an Ethernet telephone, but its characteristics make it radically different from all of those available at present. It includes the typical telephone services: emergency call (necessary and very important for the telecommunications companies) and power management for energy saving. The TRUE should have 802.1 bridge functions to switch the universal MAC addresses in the 802.1 domain. In addition, it needs to have the capability to make an Ethernet Network Address Translation (similar to the IP NAT) or to establish a tunnel, with the MAC-in-MAC procedure for example, to communicate the terminals with universal addresses over the UETS domain.

It is very important in Ethernet over voice-grade copper connections to supply power either from the Central Office (CO) like in the European ISDN, or from the switch/hub in LANs, and is a key to implement integrated Voice over Packets (VoP). This can be made with the same infrastructure (voice pairs) and functionality (power supply and battery from CO) as POTS, with all the advantages of VoP. Remote powering, via the twisted pair from the central office, makes possible the emergency calls service, guaranteed by means of batteries in the central office (this is the classical solution for the telephone network). As a reference, the ISDN and ADSL connections in Europe supply power from CO to the CPEs through POTS cables. The electric current supplied by CUE to TRUE, when connected over the telephone pairs, only needs to power the electronics of the Etherphone, as described in Figure 7.



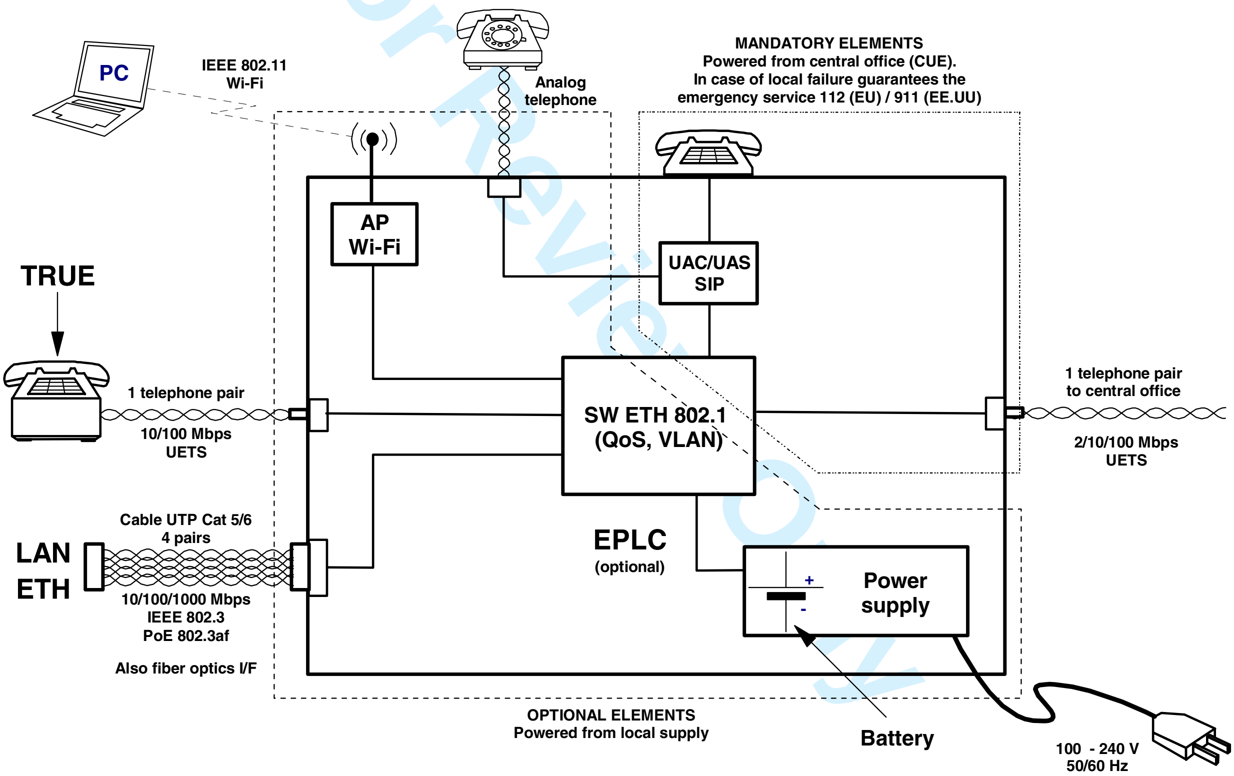


**Figure 7 .** *Block diagram for TRUE connected over telephone pairs to CO.*

The big number of connections based on Ethernet, makes it very advisable to apply power management procedures (in copper & optical fiber) in order to eliminate the consumption of "ghost power", since the average use of this connections is only a few hours/day. There is a power management specified in Std 802.11-1999, Clause 11, Subclause 11.2, that will serve as the basis to implement the control via the OAM protocol or another a specific procedure. In order to reduce the power consumed by the equipment, diverse components of this equipment can be disconnected during periods of inactivity, saving a huge amount of energy. This way, Ethernet would collaborate in the protection of the environment. Power control should be applied to the devices connected through all types of media: copper, fiber optics, wireless and PLC.

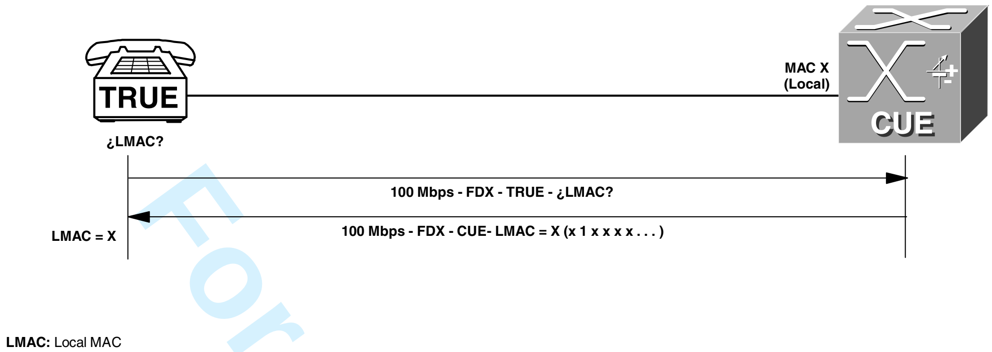


**Figure 8 .** *UETS Automatic address assignment: Auto-Negotiation.*

In the UETS CUE, the **physical addresses** are the **local MAC addresses**. The Source Address (SA) is fixed by the CUE, and cannot be changed, making the system secure. Therefore, the TRUE shall use the address that corresponds to the physical connection to the CUE. The address configuration in the TRUE can be done manually, or by the Auto-Negotiation process, as described in figure 8.

# CONCLUSION

Nowadays, everyone agrees that the future is "everything" IP. However, we should ask ourselves whether the future of the networks might be "everything" Ethernet. It is quite difficult to break with pre-established ideas, however, to progress another point of view, another perspective is needed. UETS Network doesn't compete with TCP/IP, it complements it: Ethernet is for the net, and IP is for the internet. Their own names say it.

The key is the new node concept (CUE) described herein, that uses the Ethernet Fabric Routing (EFR) technique, which switches Ethernet frames using only the local MAC addresses. The network services are offered by the IEEE 802 LLC/Ethernet "hardware oriented" protocol stack, which corresponds to Architecture of Reference's link layer, while the internet services are offered by the TCP/IP "software oriented" protocol stack, which corresponds to Architecture of Reference's transport layer. The UETS allows the integration of all the digital services over a single Ethernet-based infrastructure, providing notable improvements in speed, security and scalability. This is a radical solution to deal with the flood of traffic arising from triple-play services, strategic in the telecom carriers' Next Generation Network.

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## Biography

JOSÉ MORALES BARROSO (jmb@ieee.org) received his M.S. in Electromechanical Engineering in 1975, and Ph.D. in Industrial Engineering in 1989 from ICAI, Madrid. Member of the IEEE since 1982 now participates as a “Balloting Group Member” of the P802.3 for Ethernet Normalization. His professional career started in 1976 as a Technical Systems Engineer in the International Computer Network INFONET. Between 1986 and 1987, he was part of the design team of TESYS B/X.25, packet switching node developed for Telefónica, together with the engineers who developed the RSAN, the world’s first public packet-switched network. In 1988, he founded L&M Data Communications, and has worked there since that time as Managing Director. Professor at the ICAI Engineering School from 1976 to 1994, where he has taught classes on the Industrial Electronics and Teleprocessing Networks. He is the author of more than 34 books and various magazine articles, reports and technical documents. His book "History of Computers and Communications" was selected in 1999 as one of the best titles of the 20th Century on science and technology in Spain. He has taught over 900 courses in Data Communications technologies.