Editorial

A Case for Category 8 Copper Connectivity

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Copper Cabling has a future and ARJ45 is a big part of it

Some time ago a panel at one of the fiber optics meetings discussed a topic "How to Finally Kill Copper in Data Centers ". The question is: why kill copper? One can argue that since both: the fiber optics and copper cabling, and for that matter, the wireless compete in the area of signal transmission there should be winners and losers. However, a trip to your local supermarket should illustrate the fallacy of such an argument: if the meat and potatoes compete for a space on your dinner table – one of them should have disappeared from the supermarket shelves.

In many a discussion on the cabling infrastructure the valid technical and economic facts have been replaced by myths, and the common sense by emotional outbursts. In this author's memory no copper meeting ever discussed "killing optical fiber"

In every single case the benefits of each type of cabling need to be examined using a technical information and common sense – the decision must be suitable for a specific application. The networks of the 21st century contain now and will contain in the future multitude of means of connecting billions of users to the Internet. The fiber optics and copper cabling shall find their proper places. This paper attempts to examine the benefits of copper cabling in comparison to the optical fiber and discuss the new copper technologies for high speed communications.

Copper vs. Fiber Myth

A popular myth goes: "the fiber optics is faster than the copper because photons are faster than electrons. "The optical fiber can deliver greater bandwidth – it is true, but the bandwidth is a different characteristics from the speed. The technical term describing the signal speed is the velocity of propagation. The velocity of propagation of electromagnetic signal thru a twisted pair copper cabling is about 0.66 of the speed of light in vacuum (C), the coaxial cable allows over 0.8C. The best single mode glass fiber transmits photonic signals at about 0.71C.

Two messages sent from San Francisco: one over an optical fiber network another by electromagnetic pulse over copper cabling will arrive to New York at the approximately same time.

Cost

The panel mentioned above – could not find a sure way to kill the copper because the cost of a copper link is less than that of fiber optics. The cost of adding transceivers at the both ends of the channels is the penalty to pay for other advantages of optical fiber. The competitive cost of copper connections within the data centers (assuming 10GBASE-T switches and the category 6a cabling is about $0.50/Gbps per link. An installation cost equation includes the cost of connectors and cables proper. The copper and fiber cables are approximately at par with possible lower cost of fiber. The copper connectors are less expensive - in particular, taking in account that a duplex fiber channel needs 4 connectors versus 2 needed for a copper link.

However, the copper is even less costly if one considers the life-time maintenance and repair. In one case, the replacement of a failed copper connector (an RJ45 plug) takes 2 minutes and less than $3. A repair of a failed FO link could require the replacement of a link at cost from $50 to $250. An optical transceiver could add about 20% to the cost of a laptop computer. If you have not seen many laptops with a fiber data port lately, the cost is the reason.

A CASE FOR CATEGORY 8 COPPER CONNECTIVITY

In the fiber optics transmission, the great source of power consumption is the dual transformation of the power from the electronic to photonic signal. Per Encyclopedia of Laser Physics and Technology such efficiency is typically about 50%. The dual transformation would quadruple the power consumption in comparison to the pure electronic transmission. The fiber cabling has lower attenuation as a function of frequency. The optical fiber is energy efficient when one needs to transport a huge block of data over long distances. However, a common sense approach indicates that if both the optical receiver and transmitter are in the same building – and if you have to pay for the both transceivers' power consumption (and the building cooling) – you may want to have another look.

PoE, IoT, EMI

A huge advantage of copper connectivity is the ability to support Power-over- Ethernet (PoE) where the same cabling can conduct the power as well as signals. The majority of the network switches on the market have the built-in PoE options. The PoE also helps to dispel another myth that the copper is being replaced by wireless. In fact, each wireless transmitter commonly referred as a WAP – Wireless Access Points is connected to a copper cable. Considering the places where WAPs are installed (ceilings, attics, rafters, towers, etc.) it is often difficult and expensive to route both a power cabling and network cabling to such places. Many of WAPs have the same cable supplying the power and signals. The copper cabling PoE provides the most economical solution

A number of processes within the industrial and automated sensors generate an electrical signal. The Ethernet protocol dominates LAN; and the copper-based Ethernet over twisted wiring dominates the Premise wiring market. The Industry 4.0 is envisioned as an integral part of Internet of Things. Industry 4.0 grows from the present industrial automation by creating integral network to the office automation. The PC on an engineer's desk becomes a piece of equipment used in the production process. That process is naturally accommodated by the copper-based Ethernet protocol

The fiber has wider bandwidth, the longer reach and the optical cable is not susceptible to EMI. (The fiber optics transceivers are not immune to the EMI). The latest penetrations of copper cabling categories 7a, and 8 utilize shielded cabling. Many installations even of earlier cable generations 6 and 6a used the shielded cabling. The preferred cable construction is PiMF (Pairs in Metal Foil). According to the current marketing surveys of new installations in Europe (Germany, Switzerland, Austria, France) PiMF cable is becoming the norm - approaching 90 % of all newly installed copper cabling

The reach advantage, if examined in detail – may not be so important in some applications. Consider cases where the cabling is in the confines of a given network such as a data center or an office building. When the distance from your equipment to the next piece of equipment is about 20 -40m the ability to transmit signal over a single mode fiber at a 500m distance became moot, and it will be a waste of resources to use the fiber in the application.

New Standards for Copper

The networking industry recognizes the tremendous potential of copper connectivity and continues working on development of new standards for high speed copper interconnect. **Table 1** list some of the recent standard related to copper connectivity. The ubiquitous and rapidly growing Ethernet is a main driver.

IEEE 802.3bq a new internet standard published by the Institute of Electrical and Electronic Engineers specifies the networking protocols for 25 and 40 Gigabit/s Ethernet. The standard is a response to the industry demand for higher data density traffic in the center.

Table 1 - Major Recent Standard for High Speed Copper Interconnect

No	Major Recent Standards	Brief Description
1	IEEE 802.3bq	25 and 40 Gigabit/s Ethernet Protocol
2	IEEE 802.3bt	Power-over-Ethernet up to 100 W
3	IEC/ISO 11801-99 (in dev)	Class II , copper connectivity up to 2000 MHz
4	IEC 61076-3-110	3000 MHz copper connectors ARJ45 for Premise Wiring
5	IEC 60603-7-81	Category 8.1 connectors
6	IEC 60603-7-82	Category 8.2 connectivity
7	ANSI/TIA-568-C.2-1	Category 8 Twisted pair cabling up to 2000 MHz

The IEEE 802.3bt expands the PoE by utilizing all 4 pairs for transmission of power; it introduces Type 3 (60W) and Type 4 (100W) power sourcing equipment.

An international standard IEC/ISO11801-99 (currently in the final stages of development) introduces the Class II copper cabling up to 2000 MHz It covers the category 8 and allows in addition to RJ45, to utilize alternative connectors.

IEC61076-3-110 standard covers ARJ45 - Augmented RJ45. This is the first standard that expands the copper Premises Wiring connectors to 3000 MHz.

Category 8

In comparison to the Category 6a the Category 8 increases the bandwidth of copper connectivity by a factor of 4 from 500 MHz to 2000 MHz. The channel Return Loss is improved It is useful to note that there are two categories 8: Category 8.1 and category 8.2. In practice both utilize the same copper cables. The category 8.2 allows other connector types in addition to RJ45. The comparison between selected parameters of categories 6a and 8.1 is shown in **Table 2** - based on the TIA standards.

Table 2 - Selected Parameters. Comparison of Category 8.1 and 6a Channels

Parameter	Category 6a	Category 8
Max. Frequency	500 MHz	2000 MHz
Cable shielding	Shielded and Unshielded	Shielded
Channel length, m	100 m	30 m
No of connectors	4	2
NEXT at 500 MHz, dB	26.1	27.9
Return Loss at 100 MHz, dB	12.0	16.0
Return Loss at 500 MHz, dB	6.0	10.7

The data centers where high density of interconnect results in a large number of short transmission lines is a natural environment for category 8 applications. In this environment the ease of maintenance and repair, short distances between transmitter and receiver, in combination with a wider bandwidth of category 8 make copper cabling very attractive.

A CASE FOR CATEGORY 8 COPPER CONNECTIVITY

RJ45 and ARJ45

Two copper connectors used for Category 8 twisted pair channels are RJ45 and ARJ45 (Augmented ARJ45). The RJ45 connector is one of the most popular connectors in the world.

The network appliances, computer and data terminals have billions of RJ45 ports The ARJ45 is a relatively new connector. Augmented RJ45- was derived from RJ45 (see **Figure 1**). Presently, at 3000 MHz it is the fastest standard connector for twisted pair cabling. ARJ45 is also used with twinax cables. RJ45 and ARJ45 are very robust, inexpensive to make and user-friendly connectors.

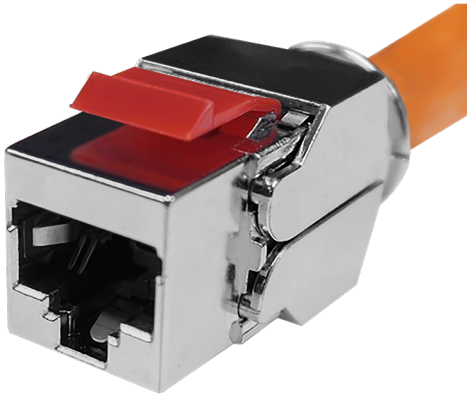

Figure 1 - ARJ45 has the same form factor as RJ45

In order to avoid any misconnection ARJ45 plug cannot be inserted in RJ45 Jack

RJ45 and ARJ45 utilize different approaches to control the Differential Near End Cross Talk.

RJ45 uses compensation to reduce the Differential NEXT: a method of creating the crosstalk equal in amplitude but opposite in phase by adding capacitive and inductive elements.

ARJ45 uses isolation to avoid differential NEXT. A Faraday cage is built around each differential pair. As a result, ARJ45 is better suited for high frequency applications.

Table 3 - ARJ45 and RJ45

Properties	RJ45	ARJ45
Contacts	8	8
Support Auto-negotiation	YES	YES
Support PoE	YES	YES
Durability Cycles Type 1	750	750
NEXT at 500 MHz, dB	26.1	27.9
Return Loss at 100 MHz, dB	12.0	16.0
Return Loss at 500 MHz, dB	6.0	10.7

Category 8 for 25 and 40 Gb/s Ethernet

The customers demand the connectivity that can be plugged into the existing 1, 2.5, 5.0 and 10 Gb/s equipment and will support 25 and 40 Gb/s switches and peripherals. Such connectivity shall deliver the robust transmission performance and support the all-important auto-negotiation The category 8 copper cabling is such connectivity.

The best way to connect the RJ45 ports and take advantage of ARJ45 performance is to combine RJ45 and ARJ45. That is commonly done by utilizing a patch cord with ARJ45 plug on one end and RJ45 plug on another end. The IEC standard design provides means to prevent plugging ARJ45 into RJ45

The category 8.1 channel shown in Figure 2 combines advantages of both: a common RJ45 and the high performance ARJ45 and delivers robust performance (see **Figures 3** and **4**). The RJ45 plugs at the channel ends allows all to utilize all the existing equipment The RJ45/ARJ45 channels fully support the auto-negotiation.

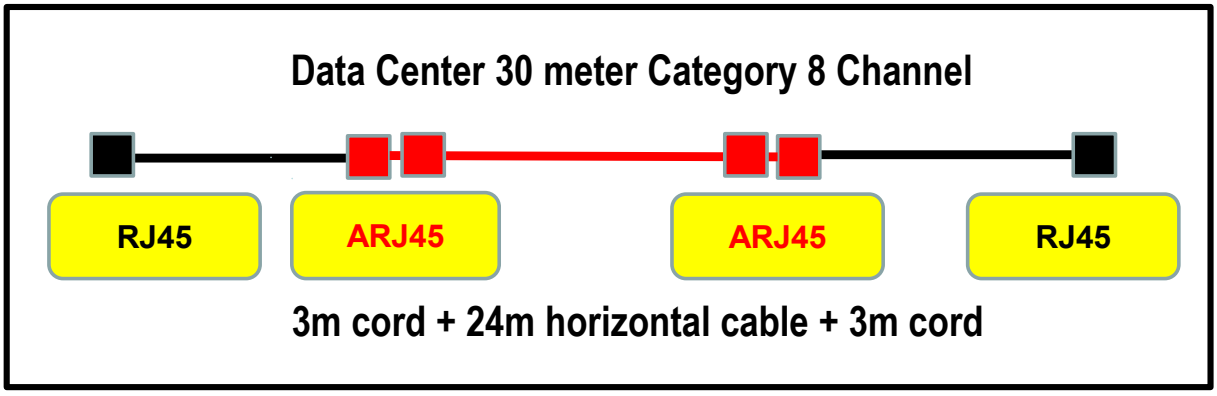

Figure 2 - Category 8.1 Data Center Channel RJ45-ARJ45 - RJ45 can connect all the existing RJ45 ports and support applications from 1 GbE to 40GbE

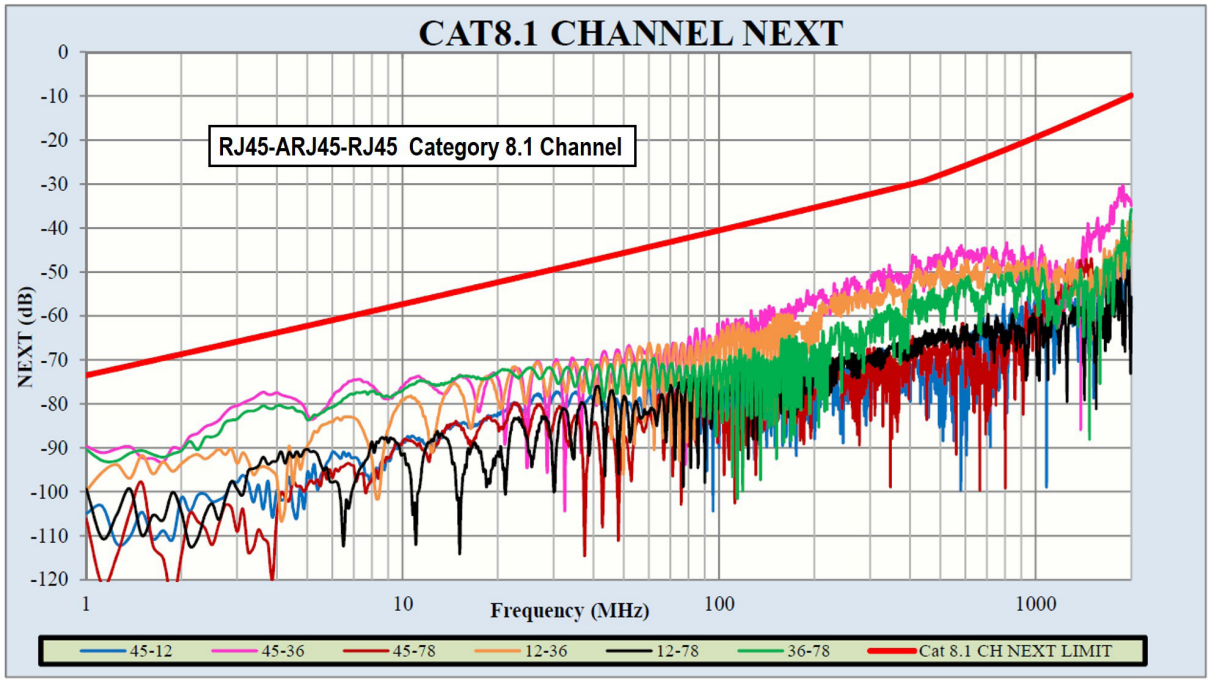

Figure 3 - Category 8.1 Data Center Channel NEXT test data

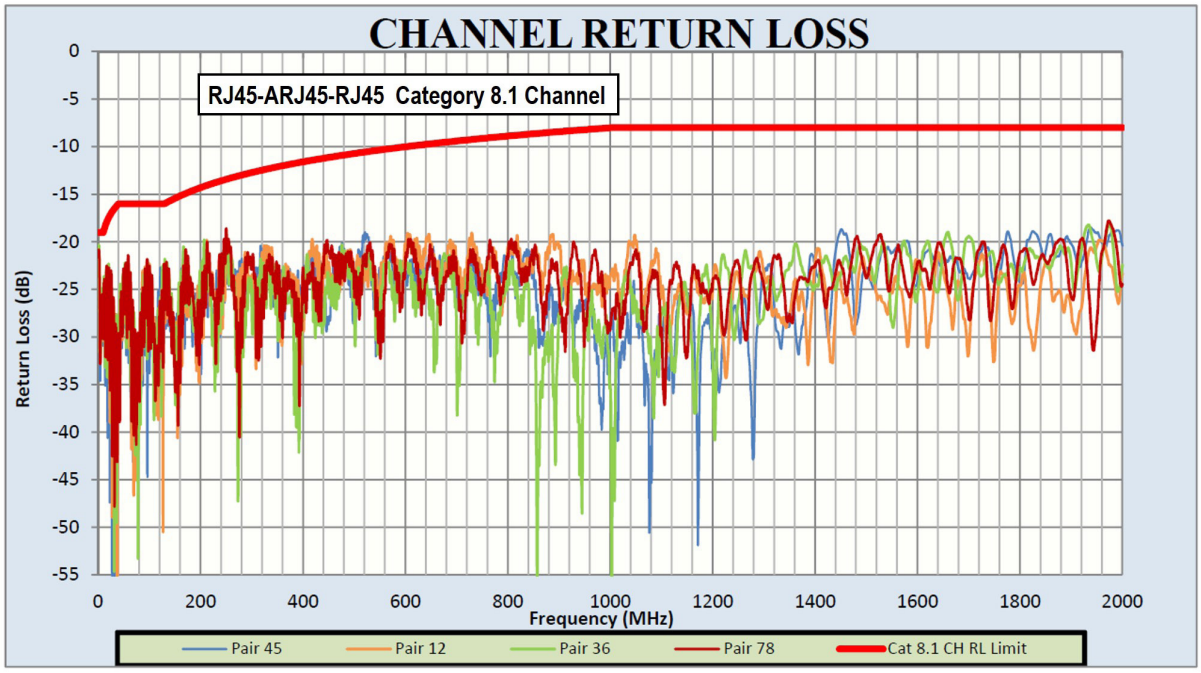

Figure 4 - Category 8.1 Data Center Channel Return Loss test data

Make no mistake – there will be copper cabling competing and complementing the fiber optics. Both optical fiber and copper cabling network will continue to coexist. The rumors of the copper cabling death are somewhat premature. Copper cabling is not dead and not going to die soon. The category 8 and ARJ45 will extend the life of copper connectivity for many years to come.

About the Author

Yakov Belopolsky, Manager, Research & Development of Stewart Connector; Member of the US TAG and a Member of the ISO/IEC committees on Connectors and Cabling. Yakov has been awarded 81 US patents and published over 30 technical papers.

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