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Open Transport Network "OTN"

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Abstract: Fiber optic technology has led to a new generation of private and industrial networks providing much larger bandwidths, high reliability and increased maximum geographical coverage. OTN or "Open Transport Network", is a transmission system specifically conceived for the needs encountered in industrial environments. OTN is based on the latest fiber optic technology to fulfill the requirements of the environments. An industrial network is characterized by heterogeneous communication requirements, such as voice, data and video. The industrial environmental conditions also dictate the equipment's level of robustness. Finally, the industrial domain prefers systems that are easy to install and easy to use, while being able to operate and develop over 10-15-year life cycles. As such, OTN can fulfill all these requirements for such environments. This paper discusses the key technical characteristics of an Open Transport Network and its applications in critical industrial sectors. Also, the beneficial of implementing the ONT technique in Libya will be discussed in this study.
Keywords: transport networks, OTN, fiber optic.

1. INTRODUCTION

Over the years, the role of communications has become very important. Today, they are of vital importance to ensure the proper functioning of many organizations and operational units.

Everybody agrees on the benefits of optical fiber. It offers virtually unlimited bandwidth over very long distances, it is relatively easy to install, and it is immune to electromagnetic radiation. Hence, the installation of fiber is considered a very secure investment. Furthermore, prices have fallen drastically in recent years and have turned optical fiber into a commodity product.

The use of light for communication purposes dates back to antiquity if we interpret optical communication in a broad sense, implying any communication scheme that makes use of light. Most civilizations have used mirrors, fire beacons, or smoke signals to convey a single piece of information (such as victory in a war). For example, it is claimed that the Greeks constructed in 1084 B.C. a 500-km-long line of fire beacons to convey the news of the fall of Troy [1]. The chief limitation of such a scheme is that the information content is inherently limited and should be agreed upon in advance. Attempts were made throughout history to increase the amount oftransmitted information. Forexample, the North American Indians changed the color of a smoke signal for this purpose. Similarly, shutters were used inside lighthouses to turn the beacon signal on and off at predetermined intervals [2].

The roots of OTN (Open Transport Network) go back to the early nineties when a new transmission technology was introduced in public networks as in SDH/SONET (SynchronousDigital Hierarchy/Synchronous Optical Network). OTN System was the first to apply this synchronous transmission technology to the industry.

OTN comes with a rich set of interface cards which allow users to connect any kind of traditional, peripheral equipment easily. This makes OTN the perfect system to migrate applications to IP (Internet Protocol) whenever the time is right. Vast investments from the past are preserved and risks are reduced to a minimum level.

OTN is the perfect solution to combine all of these services onto one high-speed, easy-to-manage fiber-optic network, irrespectively of distances. It is clear that the stakes are high: implementing all services on a single network puts the pressure on system availability. But OTN can handle all of that because it has been designed to be operational all the time, even when faults occur. The OTN system provides all elements in order to meet the requirements of local backbones and large networks. It is especially suited for mixed, stretched and private transmission network.

2. OPEN TRANSPORT NETWORK

2.1 Key Technologies Overview

SDH/SONET networks have been the workhorse for carriers for decades. The major advantage of the technology is that it provides synchronous services. This means that transmission delays are constant and predictable. This is extremely important for specific applications like teleprotection used by the power utilities or signalling applications encountered in a railway environment. Due to the increase of packet data, carriers have decreased their investments in SDH/SONET equipment over the years. OTN System has followed the trend towards packet data and has implemented unique features on OTN to handle packet data efficiently e.g. Segmented LAN (SLAN) (dedicated bandwidth for each application).

OTN makes it easy to create dedicated Ethernet LANs for individual services. Some services are better off with dedicated bandwidth on the network, bandwidth which cannot be compromised by any other applications. For example, a SCADA (Supervisory Control and Data Acquisition) system connected to an SLAN cannot suffer from interference in a CCTV (Closed Circuit Television) application. The bandwidth of an SLAN is always there, no matter the circumstances. The amount of bandwidth dedicated to an applicationis configured at set up and can be re-adjusted whenever necessary via the OMS (OTN Management System). Moreover, specific L2/3 protocols can be added to each individual SLAN. A couple of point-and-clicks on the OMS will do the job. The key features of OTN include the following:

Redundant fiber optic communication provides high capacity and immunity to interference, even over long distances.

- Bandwidth availability to each individual application, also in worst case conditions.
- Diversity of Interface Cards.
- Modular OTN network nodes facilitate maintenance and system modifications.
- Integrated network based video surveillance & recording solution exceeding 1000 cameras.
- Geographical Extensiveness of the Network:
- The OTN network allows spanning very large distances (up to 1000 km (622 miles) or more).
- Flexible System: which includes Flexibility in bandwidth allocation and simplicity in network adjustments
- Fast Error Detection and Simple Network Recovery: any ring operation and interface card errors are reported centrally, and in part also locally. Operational Simplicity ensures low cost of ownership.
- Cyber security: keep hackers out.
- Future proof: life span of 10 to 15 years or more

2.2 OTN Architecture

- As shown in Fig. 1, the OTN network architecture is based on 5 major system components:
- the fiber optic cable infrastructure
- the OTN nodes
- the OTN common logic card(s)
- the OTN interface cards providing user access to the system
- the Network Management System, called OMS.

2.3 Node Structure

For OTN-150/600/2500, two compatible node types are available to accommodate 4 (N215 node) or 8 (N22 node) interface slots (see Fig. 2). For reduced space requirements, the N2011, N2011-R70C and N2021 nodes can be used in OTN-600 networks. On these nodes, different interfaces are integrated on board. For OTN-X3M 622/2500/10G, two compatible node types are available to accommodate 4 (N415 node) or 8 (N42 node) interface slots (see also Fig. 2).

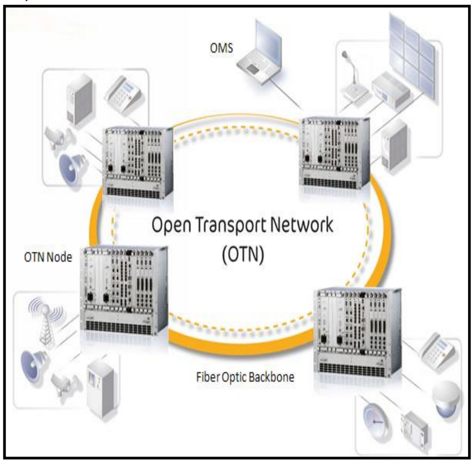

Fig. 1. OTN Architecture

1. Modular Structure

An OTN node is based on a 19" mountable chassis (standard double Euro card size). It is equipped with a number of common modules and has a capacity of 4 (N215 node, N415 node) or 8 interface cards (N22 node, N42 node). All modules are plug-in units whose front panels form the OTN node front panel.

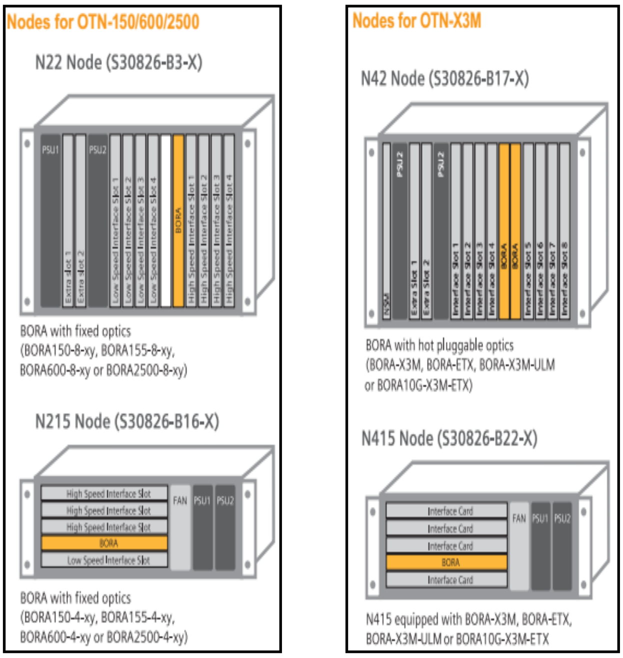

Fig. 2. Configuration overview N22, N215, N42 and N415 node

The common modules for the N415, N215 and N22 node are the (redundant) power supply(ies) and the common logic card with its two optical transceiver modules. On top of this, the N42 node can use redundant common logic cards.

2. Common Logic Card

The common logic card, called BORA (Broadband Optical Ring Adapter), implements the Time Division Multiplexing (TDM) scheme and sends the information received to the appropriate interface cards and from the interface to the optical transceiver modules.

It also holds the algorithms for various system functions such as reconfiguration and synchronization. This card also contains the connection RAM (Random Access Memory) which stores the programmed connections permanently and is protected against power failures.

Hence, each of the nodes contains its own intelligence embedded in hardware. Failures, such as cable breaks, can be corrected extremely fast (50 to 120 ms for OTN-150/600/2500, < 50ms for OTN-X3M) without the intervention of the OMS. After a complete or partial power-down, the network can be restarted without intervention of the OMS; after a self-test, the network is immediately available.

3. Optical Transceiver Modules

OTN uses different optical transceivers depending on the distances to be spanned, the required system bandwidth and the optical cable characteristics.

The optical transceiver modules are installed on the BORA, which can be equipped with fixed or replaceable optics, performing optical transmitting and receiving, the electro-optical conversion, (de)coding and clock recovery functions.

The available transceiver types are:

- Native OTN transceivers: OTR (Optical Transmitter Receiver) modules, with different characteristics:
  - for multimode and/or single mode fiber
  - wavelengths of 1310 nm or 1550 nm

   - different optical budgets
   - bandwidths of 150Mbps, 600Mbps, 2500Mbps or 10 Gbps
- SONET/SDH compatible transceivers

The OTR155 optical transceiver module can be used in an OTN-150/OTN-155 network, providing an OC-3c (Optical Carrier) in SONET mode or optical STM-1(Synchronous Transport Module) connection in SDH mode. The OTR622SFP modules used on the BORA622-X3M provide an OC-12c in SONET mode or STM-4c in SDH mode. The OTR2500SFP modules used on the BORA2500 and BORA-X3M/ETX/ULM provide an OC-48c in SONET mode or STM-16c in SDH mode. The OTR10GXFP modules used on the BORA10G-X3METX provide an OC-192c in SONET mode or STM-64c in SDH mode.

4. Power Supply Units

The power supply unit generates the voltages required for all plug-in modules: +5V, +12V and -12V. Different types of power supply modules are available for each node type.

5. Interface Slots

All user equipment is connected to the OTN system through the corresponding interface cards, which perform the conversion to digital signals to be inserted into and retrieved from the TDM frame sent on the ring. They can be removed and inserted while the power is on (hot swappable). Different interface modules are available for voice, data, LAN and video services.

2.4 Connection Types

Today's networks show a number of connection types. OTN can be used to support any of these connectios: point-to-point, multipoint, broadcast and multidrop connections.

2.5 Network Topology

The basic OTN network topology consists of a double fiber optic ring. (See Fig.. 3) One ring is used for information transport (active), the second ring (standby) is used as a backup for redundancy reasons. The network has the ability to automatically reconfigure in case of fiber breaks or node failures.

Due to the large number of interface cards that have been developed for OTN during the last decade, all applications (analog or digital) are connected directly to the network nodes (See Fig. 4). This means that no intermediate media-converters or multiplexers are used. In this way, no extra single points of failure are introduced in to the network.

Overview of the number of interface cards directly available on OTN such as audio/voice interface cards, DATA interface cards, and LAN Interfaces.

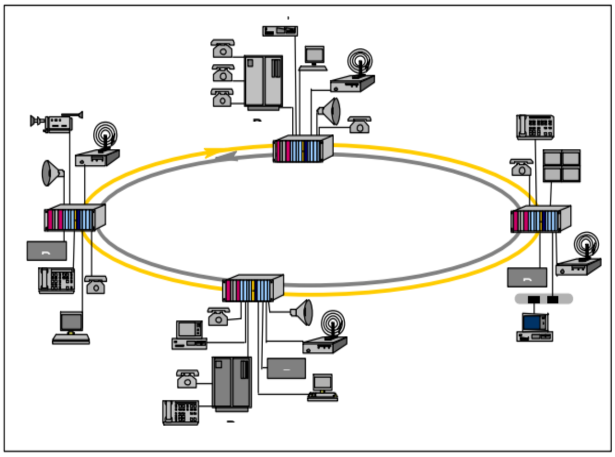

Fig. 3. Typical OTN network

Analog signals are sampled and converted to a digital bit stream on the interface cards. Then they are transported over the fiber optic network. On the other side, the signals are again converted to the original analog signal. The advantage of digital transmission is that the digital signal can be regenerated without loss of quality, thus allowing the transport of the signal over long distances (1000km).

2.6 Transmission Technology: TDM

OTN is an access and transport network, based on TDM technology. Time Domain Multiplexing (TDM) is a well-known technique in digital communications. It allows to transmit different signals, over one physical cable by allocating a timeslot to each signal. TDM is used in PHD (Plesiochronous Digital Hierarchy) and SDH (Synchronous Digital Hierarchy) transmission equipment, and also in OTN (Open Transport Network). The advantage of TDM technology as opposed to packet based technologies (such as ATM or Ethernet), is that fixed timeslots can be allocated to a signal. Because of this no information is lost (even when the network capacity is used for 100%) and timing relations are maintained. In critical environments, as for instance tunnels, every application that is connected to the main transmission backbone is considered to be important in case of an emergency. In these moments no loss of information can be admitted.

2.7 OTN Rings Types

OTN provides rings with different capacities: 150Mbps, 600Mbps, 2500Mbps and 10 Gbps. This allows the network to be designed optimally for the amount of bandwidth required by the applications. Another way of optimizing the use of the backbone capacity is the fact that bandwidth is allocated to the applications in small steps of 32kbps. In this way no bandwidth is wasted and low speed applications like analogue telephony and serial data connections (RS232,…..) can be handled in an economical manner. If required, OTN ring networks can be coupled, using the OLM (OTN Link Module). This module allows the transfer of data between rings, using an E3 (34Mbps) or DS3 (45Mbps) link. Depending on the amount of data to be transferred between rings, one or more OLM links can be used. In the case of OTN150 (150Mbps) nodes can also be connected using SDH/SONET STM1/OC3 links. This allows the creation of OTN rings, which go partially or completely over an SDH/SONET network. This also allows SDH/SONET radio connections to be used for sections where it is not possible to install fiber optic cable.

2.8 OMS (OTN Management System)

The complete OTN network can be managed using OMS (OTN Management System). Using OMS, it is possible to monitor the complete OTN network from a central location, but also distributed network management is possible. The OMS can interact with other management system using SNMP (Simple Network Management Protocol). OMS uses a relatively inexpensive PC operating under Windows NT/2000/XP as hardware platform.

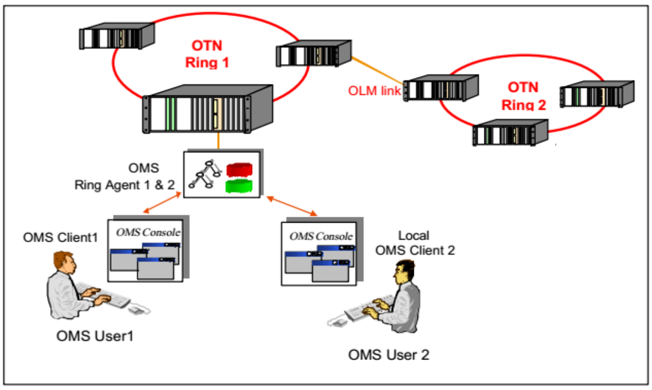

Fig. 4 OTN networking and OMS

2.9 OTN Advantages

The OTN system features many advantages when com-pared to dedicated networks for voice, data, LAN and video transmission, or compared to the traditional digital transmission systems in use today:

- The economies of different services sharing equipment and fiber.
- Easy implementation in any environment, safe guarding the investments made in the existing equipment.
- LANs can be interconnected at full bandwidth.
- Different applications have a dedicated amount of bandwidth reserved for them on the network.
- Transparent connections, making the network independent of changes in the higher layers of the various protocols.
- Easier and simpler communications wiring, and hence easier management and maintenance.

- Easy to use network management system requiring only limited training of staff.
- Automatic reconfiguration by fiber cuts.
- Best cost of ownership.
- True Quality of Service.
- Future proof: designed to have a life span of 10 to 15 years or more.

3. Digital Video Switching on OTN

Any type of video equipment (cameras, monitors, recording equipment), including the associated control signals, can be connected directly to the OTN system. The video switching capabilities are embedded in the OTN system itself, enabling any incoming picture to be displayed on any monitor connected to the OTN. This is a substantial advantage to security installations, reducing the (fiber optics) cabling enormously and reducing the extra cost for switching matrices and crossbars.

OTN's video interface cards use M-JPEG (Motion Joint Picture Experts Group) for the transmission of high quality video signals. Both PAL (Phase Alternating Line) and NTSC (National Television System Committee) standards are supported. The video-input cards (camera side) and video-output cards (monitor or recorder side) are equipped with up to four video inputs/outputs and five data ports for e.g. PTZ (Pan-Tilt-Zoom) control.

The bandwidth allocated to a channel can be assigned individually and can vary from one Mbps up to 12 Mbps. The picture quality can be customized by adjusting the colour information, the horizontal and vertical resolution and images/sec, all on a per channel basis.

4. OTN's Interworking Capabilities

Other configurations may require OTN to be used together with other types of networks, e.g. when the OTN network has to interface with existing or new SDH or SONET transport networks.

4.1 SDH/SONET Compatible Optical Transceivers

In some cases, the OTN network is required to interface with SDH/SONET equipment, e.g. when the OTN-150/ OTN-155 ring is extended or closed via an SDH/SONET network, or if an STM1/STS3c microwave radio link is used between two nodes, or when the OTN network is used as the access network on top of an SDH/SONET transmission backbone.

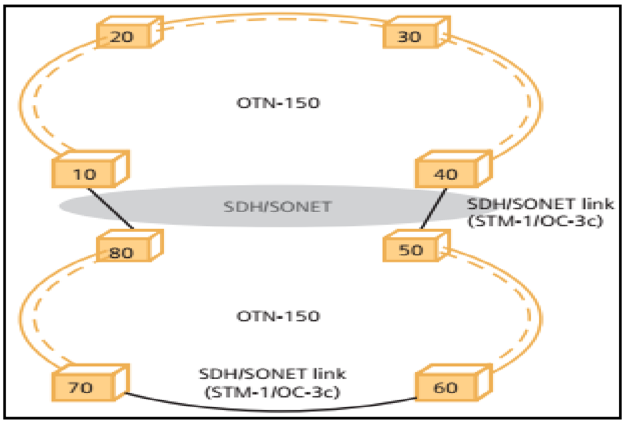

Fig. 5. OTN-150 ring is extended or closedvia an SDH/SONET network

4.2 CWDM/DWDM Compatible Optical Transceivers

OTN equipment can be used in Wavelength Division Multiplexing (WDM) applications. Using WDM technology, each application that shares the same fiber, uses a different wavelength. In this way, OTN networks can be combined with other fiber optic based communications technologies (e.g. Gigabit Ethernet or ATM) over the same fiber pairs.

For most of the OTN systems, dedicated CWDM (Coarse Wavelength Division Multiplexing) Optical transceivers are available. These "colored" optical transceivers offer 8 different CWDM wavelengths. DWDM (Dense Wavelength Division Multiplexing) Optical transceivers are available on demand.

5. OTN Applications

OTN is a robust, state-of-the-art and highly available fiber optic network system solution for critical applications in the field and not limited to lightrails, railways (Passenger - Freight), mining, pipelines (for oil, gas, water, etc…), motorways / tunnels, electricity distribution, heavy industry, sea ports, airports, security & surveillance networks, automation, private networks, cable television networks, and campus sites, … etc.

6. Conclusion

The Open Transport Network (OTN) is a private communication system providing an extension over fiber for voice, data, LAN and video communications. The system is based on "nodes", which are interconnected to two point-to-point fiber optic links creating two counter rotating rings. This topology, in combination with the system‘s built-in fault recovery features, ensures extremely high system reliability.

OTN is the ideal solution for mixed environments that are found in many stretched networks e.g. the transportation environment of metros, railways, light- rail, motor-way systems, mines and airports, along oil, gas or water pipelines, in electricity distribution networks and in the petrochemical and chemical industries. etc.

An OTN node is based on a "19" mountable chassis. It has a capacity of interface cards up to 8 cards with one or two system power supply modules, a common logic card with on-board optical transceiver modules and fan unit. All applications, such as data, LAN, voice or video, can be directly connected to the wide range of interface cards which are available for the modular OTN nodes. The common control card will then insert the application data into a predefined Time Slot on the fiber optic backbone. At the destination node(s), the data is taken from the backbone and converted back to the appropriate digital or analog format. The allocation of application data to dedicated time slots on the backbone is done by the OTN Management System (OMS). The OMS is used to configure and monitor the complete OTN network. However, since the nodes contain all configuration data, the OTN network can be operational without the presence of the OMS. The use of optical fiber and laser technology, ensures that connections can be made over very long distances (even more than 140 km between 2 nodes, network size >2000 km) with excellent transmission quality. To improve the reliability of the fiber optic backbone, a redundant fiber optic ring topology is used. This allows the OTN network to restore itself automatically in case of an optical fiber cable break. Multiple of these redundant OTN rings can be coupled to provide the optimal network topology.

The OTN product is meant for customers having vast premises, who are capable of installing their own optical fiber cabling and who need a wide diversity of communications. The maximum benefit of the system can be applied in applications such as railways, subway and tram networks, pipelines, intelligent highways, tunnels, airports, mines, industrial plants, harbors, …etc.

7. Recommendations

- The OTN product is the undisputed market leader in metro & lightrail, railways, oil & gas and the mining industry. So, we recommend to employ this standard in the reconstruction phase of Libya.
- A campus site is a complex site in which many different buildings are distributed throughout a large private area, we suggest to employ this standard in the campus’s own network such as university campus, iron and steel complex, Oil fields and so on.
- OTN Systems are the leading supplier of networking products for critical infrastructure worldwide. For this reason, future several researches are needed to identify this product. Highly recommendation can be forwarded to researches and scientist in order to clarify and develop this technique and how to get benefits from it in our Libyan societies.

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