WHITE PAPER

Infinera

The Magic of Big Capacity: Boosting Railroad Infrastructure ROI with Telecom Services

Infinera enables owners of optical fiber networks to significantly expand their capacity, offer new revenue generating services and match capital costs to capacity demand. Infinera's services include a full range of design, turnkey network upgrading and installation of equipment, remote management and on-demand switching on of pre-installed capacity. This white paper identifies some of the revenue opportunities available to holders of railroad rights-of-way.

Introduction

Railroads represent, in most European countries, a set of pre-authorized utility pathways, also known as "rights-of-way," which have been or can be used for laying down fiber optic cables. The table below lists the number of kilometers of rights-of-way in selected European and adjacent countries, representing nearly 400,000 kilometers of revenue opportunity. There are two important reasons why this pre-authorized routing is so valuable.

First, in many cases, fiber optic cable has been laid down and often significantly depreciated. These assets can easily be revitalized by upgrading to increase capacity and service capabilities, thus adding significant revenue opportunity. By leveraging the latest advances in fiber optic communications technology, railroad operators can now offer new, higher-revenue, high-speed services and/or offer large amounts of bandwidth wholesale to other network operators. This type of capacity expansion, which involves relatively straightforward equipment upgrades, is difficult for other network owners who have already installed fiber and do not have equivalent rights-of-way to match. Infinera, a world leader in advanced optical networking, has extensive experience in high-speed network upgrades of some of the world's most advanced optical fiber networks in terrestrial as well as the more difficult and technically challenging submarine networks. Infinera also offer a full range of services including network planning and design, turn-key upgrades, and equipment installation, and outsources management services of the network.

A key component in the Infinera solution is the advancement of photonic integration, which is designed to enable the highly complex optical components to be integrated and miniaturized into a highly reliable Photonic Integrated Circuit (PIC) about the size of your smallest fingernail (See figure 1). The use of PICs has dramatically changed the paradigm of optical networks, enabling them to be smaller, more reliable, more efficient and, most importantly, significantly easier to use than traditional optical networks that leverage discrete optical components.

Figure 1: The Infinera PIC consolidates all the key optical components used in dense wavelength division multiplexing (DWDM) optical transport systems onto a single chip smaller than a fingernail.

Selected European and Adjacent Countries	Track in Operation (kms) 2011	Selected European and Adjacent Countries	Track in Operation (kms) 2011
Austria	5,066	Macedonia, FYR	699
Belarus	5,503	Moldova	1,157
Belgium	3,578	Netherlands	3,016
Bosnia and Herzegovina	1,026	Norway	4,114
Czech Republic	9,569	Poland	19,702
Denmark	2,131	Portugal	2,843
Estonia	787	Romania	13,620
Finland	5,919	Russian Federation	85,292
France	33,608	Serbia	4,058
Georgia	1,566	Slovak Republic	3,587
Germany	33,708	Slovenia	1,228
Greece	2,552	Spain	15,317
Hungary	7,893	Sweden	9,957
Ireland	1,919	Switzerland	3,543
Israel	1,034	Tunisia	1,119
Italy	18,011	Turkey	9,594
Latvia	1,897	Ukraine	21,705
Lithuania	1,767	United Kingdom	31,471
Luxembourg	275	**Total Track (kms)**	**369,831**

Figure 2: Rail lines are the length of railway route available for train service, irrespective of the number of parallel tracks. **Source:** http://data.worldbank.org/indicator/IS.RRS.TOTL.KM

Second, because the growth in broadband is being driven by (1) increased usage of mobile devices (many of which are used at stations and on trains), and (2) streaming video, the demand for low cost bandwidth is growing rapidly while the cost of expansion is going up. It is a little-understood fact that traditional telecom operators obtain high revenue per bit for voice traffic, but are now faced with the simultaneous problem of expensive capacity expansion and a revenue per bit that is two to three orders of magnitude less than that for voice. While LTE is roughly twice as efficient as third generation wireless solutions, it is insufficient by itself for profitable telecom services growth.

The Revenue Opportunities

For railroads owning extensive rights-of-way, telecom services offer a variety of ways to monetize their investment, including:

1. Providing wireless accessible broadband capacity to rail operators travelling over an owned rail network.
2. Providing enhanced security and other services to rail operators travelling over an owned rail network.

3. Monetizing existing fiber optics laid along the right-of-way by selling capacity or back-up backbone capacity to traditional landline carriers who are running out of capacity in their own networks due to streaming video and increased traffic from mobile device usage generally.
4. Providing a backbone network for mobile companies running into backhaul capacity limits for their cell towers. In some cases, mobile companies will expand their unregulated WiFi networks, which will also increase traffic on backhaul to their network.
5. Offering a risk reduction option to large content development networks that wish to increase the resilience of their network, an option previously only available through major carriers.
6. Offering capacity insurance capability for integrated, landline, cable or mobile carriers or other large clients for whom downtime is particularly costly.
7. Creating an alternative backbone for supporting GSM-R for train scheduling and control, and enabling wireless or satellite links to create high speed mobile data access for train passengers.
8. Offering peak capacity services for carriers or content owners facing large spikes in demand, e.g. due to significant events such as the World Cup or the Olympics.
9. Setting up a Mobile Virtual Network Operator (MVNO), either singly or in joint venture with other railroads, which may have appeal in some cases.

The On-Board Passenger Network

Passengers have come to expect the availability of high speed data connections while on board trains. The easier it is for passengers to connect, and the lower the bandwidth cost, the more traffic and passenger loyalty will be generated. In addition to standard WiFi services, one can easily imagine premium services being offered by railroads, single-railroad or joint-venture MVNOs or existing operators that offer either LTE or 4G services to passengers. 4G microcells are

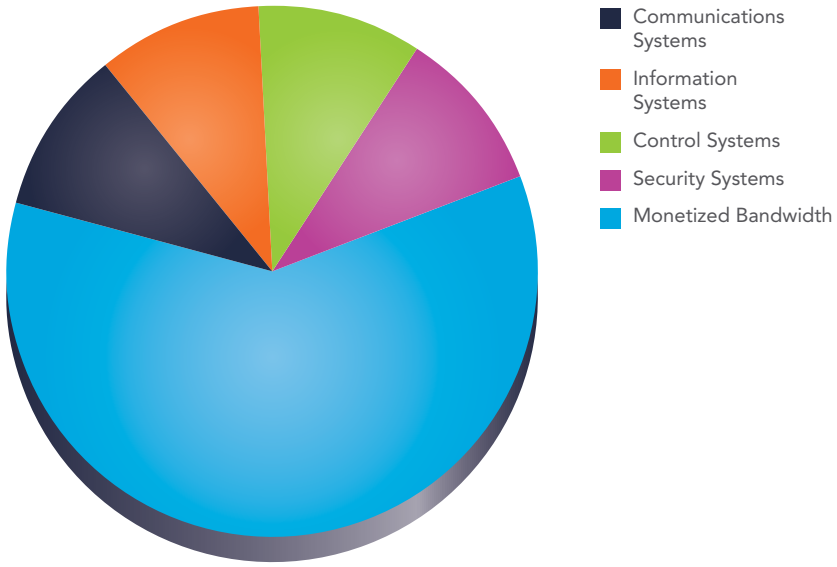

Figure 3: Monetization of the unused fiber capacity provided by the Next Generation DWDM systems

now widely available for homes with poor 4G reception, and similar capabilities are available for trains.

Various combinations of long-haul optical and wireless technologies also are or may become available for tracking trains, containers, packages and perhaps even customers. One could imagine, for example, video cameras tracking individual containers in areas where security is a concern. Tracking, scheduling and coordination all have different reliability and resilience requirements. Such wireless technologies that have been installed or will be installed that meet Infinera network requirements can be fed into the network and given a privileged dedicated channel to avoid latency issues.

Perhaps even more importantly, the availability of large quantities of bandwidth ensures that video feeds can be of high quality. In a world of massive information overload, the human brain is specialized for absorbing information most quickly through visual displays and video, but only if the quality is high. More than 50% of traffic on the Internet is now video. High quality video will also become one of the major drivers of telecom capacity consumption for railroad networks, whether for ongoing monitoring, security, or post-event analysis.

In terms of train-to-backhaul communication, the traffic from the train would be aggregated and connected with local base stations via microwave, WiMax, WiFi, satellite or some combination of connectivity. These base stations may be linked to each other or linked to a node in the optical transport network running alongside the tracks and/or other carrier backhauls.

Building/Upgrading the Network to Realize the Revenue Opportunity

There are seven big things to understand about the economics of railroad telecom networks:

1. **Installing equipment and fiber is labor intensive and expensive.** By upgrading existing optical fiber with higher capacity equipment, such as Infinera DTN-X, one can dramatically increase fiber capacity without the expense of laying new fiber or lengthy regulatory approvals. That's particularly true for submarine networks, where network capacity is easily doubled and tripled. Infinera also offers a highly advanced on-demand bandwidth solution so operators can deliver services their customers need, without waiting the typical six to eight weeks for networks to be provisioned, or equipment to be delivered. Infinera's photonic integration is designed to allow operators to rapidly and cost-effectively deploy service-ready capacity, and pay for it only as capacity is actually turned up in response to customer contracts, enabling rail operators to match capital outlays to revenues as they grow.

   Service-ready capacity that is tied directly to a revenue generating customer, supplied in 100 Gb/s capacity increments, enables operators to easily win new business with speed as a competitive advantage. Activating additional capacity is as simple as acquiring a license and entering the license activation code. No installation required. No time delays. No new testing. Immediate revenue.

2. **Telecom is fundamentally about having inexpensive "big fast pipes."** Optical fiber offers the largest capacity available today. Big capacity means no delays and fast transmission. Since its first product launch in 2004, Infinera has pioneered and provided the leading edge in capacity, with today's Infinera DTN-X platform offering super-channels with transmission rates of 500 Gb/s and the ability to multiplex up to 9.5Tb/s of capacity on a fiber cable. That's roughly equivalent to transmitting 9,500 two-hour movies (or 2,250 HD-movies) for mobile devices in one second.

3. **Flexibility matters.** If you have not been involved in optical transport networks, you may be surprised to learn that they are very fast, but have historically been extremely inflexible. Reallocation of optical bandwidth (the amount of capacity), and changing the services or customers assigned to that piece of capacity was slow and labor intensive, generally requiring a visit by a human engineer to a node on the network connecting two regions of optical fiber. In contrast, Infinera capacity can be reassigned in real time or close to real time from remote locations without an expensive human visit to the switching location. We believe Infinera is the leader, by far, in this capability. In fact, Infinera holds the Guinness World Record for network provisioning speed (8 Tb/s of capacity redeployed from a remote management site in less than 20 minutes).

4. **Telecom technologies can be confusing with all the things they do.** And each new offering requires lots of different and highly specialized equipment. But underneath all the myriad pieces of equipment at lower levels in the network (referred to as Level 0/1), you need a super-highway or a "super-channel" that is big enough to handle whatever you want to pump down it: time sensitive safety and scheduling information, a backbone for a data oriented data network, video of all types from safety video to video requested by passengers over their cell phones. Infinera provides that capacity and it makes it available to just about any equipment or communications protocol. Even with new optical equipment, you can continue to maintain existing purchased telecom equipment or hook up current and next generation equipment.

5. **You need to be able to handle the big delivery problems in telecom today.** The expectations of customers have changed. Corporate customers and regulators want more real-time tracking data than ever before. Individual consumers want fast inexpensive data access and bandwidth-intensive video on their mobile devices. Carriers would like to exploit your right-of-way to reduce the cost of network capacity expansion. What makes these needs challenging is that traditional voice had high revenues per byte of data transmitted. Today's demands require capacity to be priced at two to three orders of magnitude less. Revenue per bit is 100-1000 times less for data than it used to be for voice. You need efficiency with both low-cost capital and low-cost operating expenses.

6. **Maximizing throughput.** Like the owner of an apartment building who does not want apartments remaining empty because they create no revenue, an operator of optical fiber networks does not want to have "stranded capacity" that generates no revenue. Infinera

equipment's ability to dynamically reallocate bandwidth means that stranded capacity is minimized. Lost revenues are minimized as a result. And Infinera's Instant Bandwidth, which allows the switching on of installed and unused capacity, can help win new business from clients in a hurry for capacity.

7. **Resilience.** Because Infinera is the most dynamically re-allocable capacity on the market today, rerouting of capacity to other parts of the network is easy if, for some reason, an accident damages a particular stretch of fiber optics—assuming of course that you have access to alternate routings on your own or third party networks. It also makes possible the offer of back-up capacity to other networks not located on the railroad right-of-way. Infinera's hybrid photonic integrated circuitry is particularly reliable and as of the date of this paper has not failed in the field.

8. **Reliability.** There is a relation between the reliability and maintainability of Communications Systems and availability of railway services. Infinera products' unmatched reliability thanks to the PIC component associated with end-to-end digital node operations drastically improves the availability of communication networks compared to traditional solutions

Infinera, a leading edge provider of high performance optical transports with its DTN-X product line, offers 500 Gb/s capacity. It can be retrofitted into most existing optical networks, installed in days rather than weeks, and capacity can be over-deployed with the purchaser, which then pays for capacity when it is switched on in 100 Gb/second chunks.

Regulatory Control and Risk Management

The European Rail Traffic Management System (ERTMS) is designed to enhance cross-border interoperability and provide a single European standard for railway signaling. Its focus is, however, on the operations of rail businesses, not on revenue generation. ERTMS has three

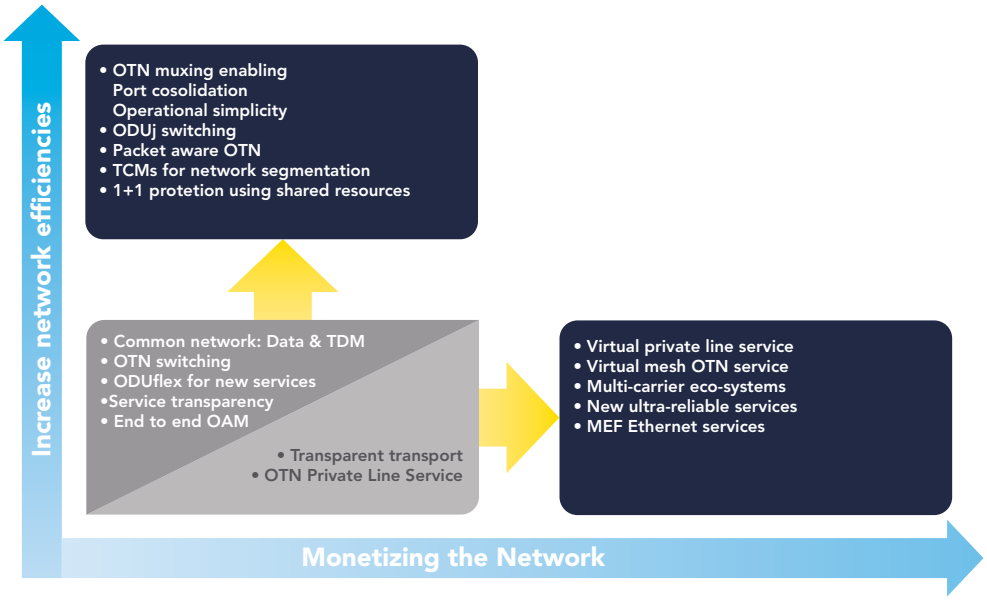

Figure 4: Key Drivers for Network and DTN-X Evolution

basic components: GSM-R, the European Train Control System (ETCS), and European Traffic Management Layer. GSM-R is a wireless protocol based upon GSM. ETCS is focused upon authorizing train movement, reducing complexity for drivers and providing information to on-board driver displays. ETML is designed to support optimization of traffic, schedules and scheduling adjustments. ERTMS is currently a relatively low-bandwidth set of applications. It is mainly focused upon efficiency, safety and integration of decision support information for drivers and control centers.

The introduction of ERTMS represents an important step for improving the management of inter-operating rail networks. Issues such as Quality of Service (QOS) latency and hand-offs between wireless nodes are obviously important. But the capacity of a network set up only to support ERTMS is likely to be insufficient to enable the revenue opportunities resulting from providing high speed broadband for passenger mobile devices.

Transitional Architectures and Next Generation Architectures

Rethinking railroad network telecom can be considered in two ways: a gradual replacement of less cost effective and inflexible technology, and generational upgrade strategies.

Railroads will inevitably do both. For any decision maker in a rail firm, there are always going to be five important questions:

1. Where do we want to lay down or upgrade fiber?
2. At what points in the fiber network should we install wireless access to the backhaul network?
3. What is the topology of our network so that we can reroute traffic in the event of backbone or wireless base station problems?
4. What technologies (WiFi, 4G, GSM-R/LTE, Satellite) will we use or combine for communicating with the moving passenger or railcar?
5. What fixed location sensors will we use to detect activity on the track and how will they be linked to the backbone?

Note that issues of protocols and standards are largely secondary. Infinera's technology is carrier grade. Its capacity can be simply and easily reallocated to different switching equipment and different protocols. The only real questions are economic: When do we decide to "End of Life" a protocol or technology? When do we offer more services in order to create more revenue?

Further Reading and References:

1. Infinera web site: www.infinera.com
2. Wikipedia: http://en.wikipedia.org/wiki/Infinera

Infinera Corporation
140 Caspian Court
Sunnyvale, CA 94089 USA
Telephone: +1 408 572 5200
Fax: +1 408 572 5454
www.infinera.com

Have a question about Infinera's products or services?
Please **contact us**.

Specifications subject to change without notice.

Document Number: 0193-WP-RevA-0519