# Cost Considerations in 40G Networks

June 2008

INFONETICS RESEARCH

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# I. Executive Summary

Our lives as consumers and employees are changing—the way we work, live, and play is quickly moving toward a more connected and competitive world, and video is an increasing part of it. We are moving toward the ability to communicate and have access to important information or entertainment at any time, any place, and on any device, fixed or mobile. These changes depend ultimately on optical networks to carry the traffic load.

Traffic has always and will always keep growing, and this pushes the need to increase the capacity of optical networks. Today, optical backbones and metro core networks are predominantly 10G, on the verge of moving to 40G. But the challenges in the previous move from 2.5G to 10G are minor compared to those of moving from 10G to 40G, and the challenges moving on to 100G are even more daunting.

Increasing the line rate 4x (by moving from 10G to 40G) or 10x (10G to 100G) causes nasty problems—impairments—due to the physical properties of light passing through glass fiber. These changes create a higher baud rate (symbol rate), which has effects, including reducing light signal strength, shortening reach, increasing sensitivities to chromatic dispersion (CD) and polarization mode dispersions (PMD). Various remedies are available, but are typically expensive—these include more amplification (e.g., RAMAN), DC fiber to combat CD, optical PMD compensators, and adding electrical regeneration points. Recent advances in DSPs have been shown to be a practical solution to these impairments, when compared to traditional optical methods, and can be used in 40G and 100G systems.

The optical fiber plant plays a large part in what can be achieved in moving to higher line rates, and a number of studies show that a lot of fiber in the ground is susceptible to unacceptable levels of PMD. The fiber plant PMD problem will not go away, as it often not feasible to install the latest PMD tolerant fiber on any route that will be upgraded to 40G (or 100G). So, the answer has to come from innovation in PMD and CD compensation, or modulation techniques that avoid these issues by using a 20G or 10G baud rate.

There are 4 main modulation schemes being used or considered for 40G (and 100G). These schemes are Duo-Binary, DPSK, DQPSK, and DP QPSK—each technique attempts to minimize the various impairments, while minimizing the cost of the equipment.

Service providers need to ponder many technical considerations to choose the right 40G technologies and products, yet there are many pragmatic requirements:

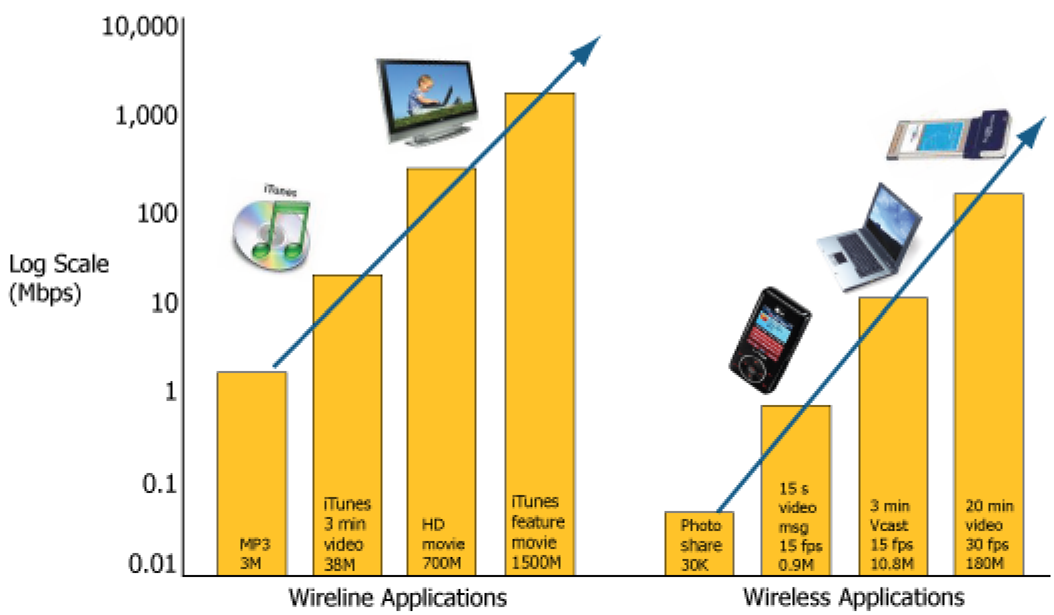
- 40G fits into 50GHz spacing, so 40G wavelengths can go through any OADM and ROADM filters in the network (spectral efficiency)
- 40G boards operate in existing 10G equipment
- 40G does not diminish reach
- The number of OADMs and ROADMs allowed on a path is not reduced
- Investment in additional electrical regenerations, compensation equipment, and amplifiers is minimized
- 40G, 10G, and 2.5G in different wavelengths are on the same fiber, as 100G should be in the future
- Equipment is ready for 100G

# II. Trends Driving the 40G Market

## A. A Fast-Changing Market

This paper is about the growing phenomenon of higher capacity service provider optical networks, and the use of 40G wavelengths in particular. Of course, service provider network capacity has always been growing, never diminishing. In the past 2–3 decades, we have experienced an unbroken cycle of introducing a level of bandwidth for consumer and corporate use, which opens the door to new possibilities and begets new applications that use even more bandwidth. Today, wireline and wireless applications are traveling on this upward path.

**Exhibit 1 Wireline and Wireless Applications Use More Bandwidth**



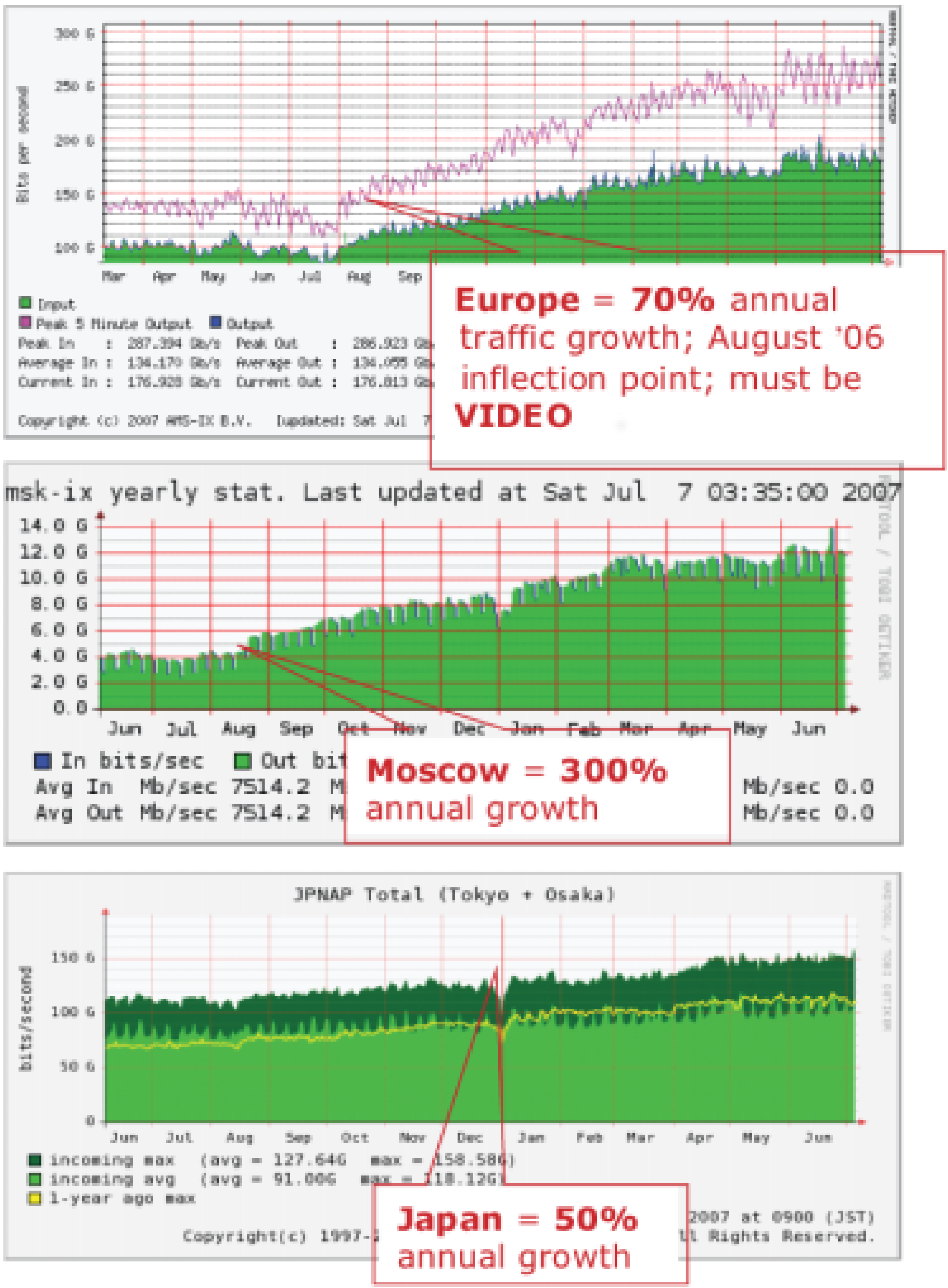

We are in the midst of unprecedented communications changes that affect the daily personal and work lives of consumers and businesses in just about every country in the world. We live in a connected, competitive world—our lives are moving at an increasing pace, and we clamor for the efficiencies brought on by the ability to communicate whenever we need or want to. Networking has helped change the daily ways we operate and the way we will operate in the future. The quickened pace has given many people a business or personal advantage, and this in turn has accelerated the demand for communication and access to important information any time, any place, and on any device, fixed or mobile.

## B. Traffic Is Growing at a Quickening Pace

There are debates in the telecommunications industry about how fast traffic is growing, so we include some hard data from a few representative points in the world—at some key Internet Exchange (IX) facilities. These are major Internet interconnection points, where service providers and content providers interconnect their networks at a common location.

One of the main IXs in Europe is the Amsterdam exchange, know as AMS-IX. We show its data in Exhibit 2 (next page), where an inflection point occurred in August 2006, tipping the slope of traffic growth upward; it grew 70% by August 2007. No specific event caused this long-term change, but we and many others attribute it to the growing use of video, including social networking sites and phenomena such as YouTube and MySpace. In Japan, video and mobile services have been at play for several years, and we see a 50% traffic increase between August 2006 and August 2007. In the emerging market of Russia, we see a monstrous 300% increase at the Moscow IX in the same period.

**Exhibit 2** **IX Traffic Increases 50%, 70%, 300% in One Year**




These examples of IX traffic growth are not the end of the story. We expect IPTV to be a factor, but IPTV has no real effect on traffic yet, with a very small number of subscribers. Over the next 5 years, there will be more personalization of video—whether it is broadcast programming, news clips, or other topical video content on a person's request list, or is made available due to the user's interests and demographic profile, whether via IPTV or "over the top."

Some recent data supports these trends. The December 2007 comScore (www.comscore.com) report revealed that US Internet users watched more than 10 billion videos online during the month, representing the single heaviest month for online video consumption since comScore initiated its tracking service. An estimated 81 million people, or 63% of the 129 million people who access the Internet over broadband in the US, watch broadband video at home or at work, according to new research conducted by The Nielsen Company for The Cable & Telecommunications Association for Marketing (CTAM). This is a jump of 16% in just 6 months (from 70 million in September 2006).

The sheer number of subscribers is generating more traffic—in 2011, Infonetics expects there to be 4.4 billion mobile telephone users, over 470 million broadband subscribers, and over 90 million IPTV users. As these numbers swell, so does the average amount of bandwidth delivered for their services each year. With all these factors considered, there will be no stopping the growing gusher of bandwidth required on optical networks.

## C. IP Network Transformation—Larger Networks

There is another factor at work as well. Most providers around the world have or are planning "IP network transformation" projects to move fully to a data/packet based network. Providers are moving to a single packet network by combining the traffic and applications from multiple "stovepipe" or single-purpose networks (for example, voice, broadband, and several data networks). A single network is naturally larger, requiring higher capacity.

Infonetics believes the hallmark of the ultimate transformed network is an IP/MPLS/Ethernet data service layer over a "fused" Ethernet-DWDM transport layer. The ETH-WDM transport layer relies heavily on ROADM gear, and is deployed in rings and mesh; it will incorporate Ethernet transport tunnels (such as PBB-TE, T-MPLS, etc.), use OTN (G.709) to carry any service transparently, and will be managed by ASON/GPMLS control plane. Although this transport may carry SDH or SONET services, it will eventually not use a SDH/SONET layer. Therefore, SONET/SDH will gradually decrease across 10–20 years, as WDM becomes the dominant transport layer.

## D. The 40G Market

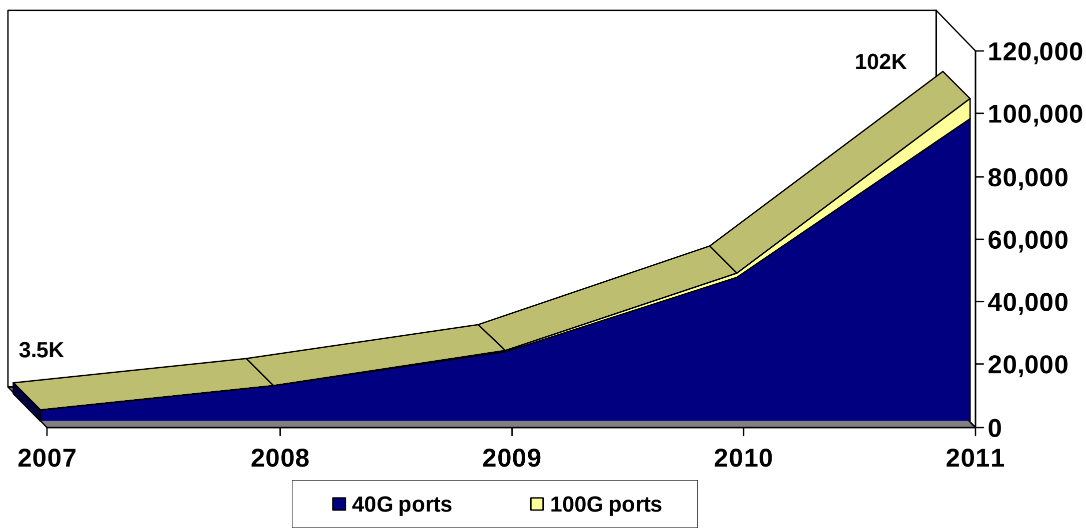
Ever-more bandwidth hungry applications, rising populations of network subscribers, business and personal competitiveness, and the use of more video have pushed us to the point, where, today, the standard optical backbone is built of 10G links, with many metro core networks at 10G as well. Service providers have a growing number of customers connecting their largest sites with 10GE. Infonetics forecasts over 1.4 million 10GE ports on routers and optical equipment in carrier networks in 2010. With this backdrop, it is natural that 10G traffic will be aggregated onto 40G, so we find the 40G market coming into focus.

Service providers have huge investments in their 10G networks. Their networks continue evolving to minimize regens and leverage ROADM functionality to reduce cost and improve network flexibility—they are evolving toward all optical networking. These capabilities have been delivered through additional system reach at 10G. To continue cost per bit reduction when volumes of 40G and 100G ramp up, these systems have to build on existing network configurations and design criteria with best in class 10G networks. In other words, 40G and 100G systems need to preserve the reach for network savings, as well as 50GHz spacing, and other issues we will discuss later.

The 40G market is undeniably growing—with thousands of ports deployed in 2007, the ramp has begun. This is clearly portrayed in Exhibit 3 below, which charts the number the physical 40G ports on IP routers and WDM gear installed in carrier networks. The growth in this early, fast growing market is at a CAGR of almost 130% (2007–2011). In this paper, we explore the trends driving the 40G market, the many difficulties encountered in optical fiber networks when moving to higher capacities, some of the techniques used to achieve 40G, and a look at why the 40G market will grow before 100G becomes a reality.

**Exhibit 3** **40G and 100G Ports on Router and WDM Equipment**




# III. Moving to Higher Line Rate Systems

## A. The 3 Basic Challenges of Moving from 10G to 40G (and 100G)

Telecommunications service providers face a set of challenges when they consider deploying 40G technology in their networks. We have compiled a checklist of questions for carriers to ask when considering 40G technology (see *Conclusions)*, and our checklist digs into the single issue of how the new 40G technology affects the current installed network. This high level issue is the same when considering 100G systems, and was the same when considering upgrading from 2.5G to 10G. Many in the industry focus on the all-important cost of equipment, and it is necessary for the price of a 40G link to be under the price of 4 10G links to pave the way for a broad market. However, equipment price is one of many considerations, and may even be relatively unimportant if the network line design has to change, new 40G equipment forklifted in, expensive active compensators added, or new fiber deployed.

Carriers would like to upgrade to 40G by just inserting new 40G cards into their existing 10G WDM systems, without making any other changes. Depending on the solution, this may or may not be possible. Carriers see their 3 basic strategies in moving from 10G to 40G as:

1. Use the current fiber plant of the 10G routes, and not invest in expensive deployments of new fiber for 40G
2. Add 40G (and 100G in the future) to currently installed equipment, so additional equipment is not required to sit alongside the 10G gear
3. Keep the network robustness and architecture intact, that is, the current line design, so that the numbers of OADM and ROADM nodes on any pathway in a ring or mesh do not need to be reduced

For the rest of this chapter, we will present factors and aspects of these challenges, which are summarized in Exhibit 4.

**Exhibit 4 Optical and Fiber Effects when Moving from 10G to 40G to 100G**

| | 10G | 40G | 100G | Typical Mitigation | Impact |
|---|---|---|---|---|---|
| Symbol rate | 10G | 40G | 100G | Higher speed electronic | Cost challenges |
| ITU grid optical spectrum occupancy | 25/50Ghz | 100Ghz | 200Ghz | Limitation on number of OADM/ROADM | Less flexibility in network design; marginalization of higher rate solution |
| OSNR (signal intensity, quality) | 0dB | -6dB | -10dB | Reach reduction, or deploy Raman amplifiers | Significant reach or cost |
| CD (chromatic dispersion) tolerance | 1 | 1/16 | 1/100 | Involved dispersion map and active dispersion compensator | Deployment and planning, cost |
| PMD (polarization mode dispersion) tolerance | 1 | 1/4 | 1/10 | Fiber selection, fiber upgrade, PMD compensators | Deployability, cost |

## B. Optics and Fiber Properties Affect Higher Line Rates

We will start with some fiber and optics basics. When light is transmitted through a fiber at 10G, there are a number of problems or "impairments" encountered depending on the type of fiber and the link length—all solved in today's 10G equipment. When the rate of the signal is sped up by a factor of 4 (and a factor of 10 for 100G), many of the impairments present at 10G are magnified. This forces the need for new or innovative technology solutions to keep costs, footprint, power consumption, heat, etc., in line, while quadrupling capacity and not disturbing or limiting the resiliency and robustness of the network.

### *40G Symbol Rate at 25ps Rather than 100ps at 10G, and OSNR Drops*

A unit of information, called a symbol, transmitted at 10G takes 100 pico seconds (100ps), and that symbol transmitted at 40G takes 25ps. This means the receiving end that translates the light back into a symbol is dealing with only 25% of the light of a 10G symbol, which amounts to a 6dB OSNR (Optical Signal to Noise Ratio) drop. The OSNR is a measure of the strength of the signal, and a drop of

6dB usually means that the reach or link length must be reduced by 75%. The implication of this is that the receiver must be more sensitive and use more complex materials; typically, this means it is more expensive. It also might necessitate the deployment of expensive and somewhat tricky RAMAN or other powerful amplifier technology for the 40G links, as well as more frequent electrical regens.

### *Chromatic Dispersion (CD) Increases by a Factor of 16*

As a signal travels through a fiber, CD causes the pulses constituting the signal to spread in time. If this spreading is not compensated, these pulses will overlap, rendering the signal unusable. Comparing to 10G, this effect is 16 times more pronounced at 40G and 100 times more pronounced at 100G. This poses a serious roadblock for systems operating at a higher line rate.

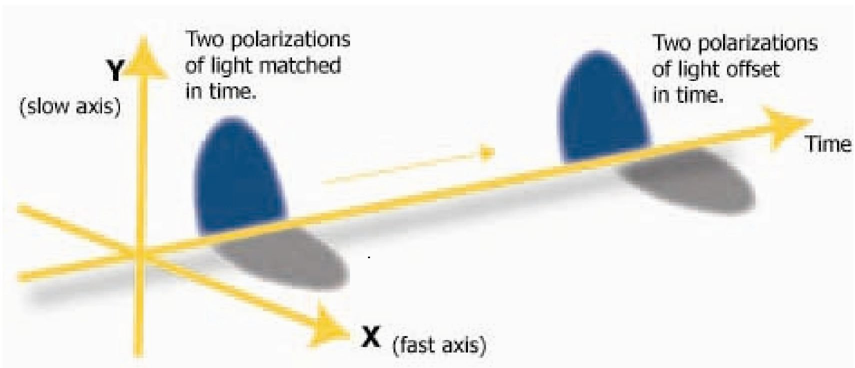
The usual CD remedies include a number of compensating techniques, such as bulk compensators and tunable sub-band compensators. Operators treat their 10G networks for CD by inserting DCF or dispersion compensating fiber, which bears a burden of engineering to compute a DCF map, and calculate which and how many of various options of DCF coils is appropriate for any span or link. This remedy is nastily magnified by speeding up to 40G. Carriers wish for a sane and un-complex alternative.

### *Polarization Mode Dispersion (PMD) Increases by a Factor of 4*

Polarization Mode Dispersion (PMD) is another distortion—probably the harshest to overcome. This occurs due to infinitesimal imperfections in the circularity of the core of a fiber, which can be the result of the material itself, manufacturing process, or stress in the field caused by bending or twisting. The effect of PMD on the light pulses constituting the signal is similar in nature to the one created by CD. However, it cannot be compensated as systematically as it was for CD, and above all, the PMD impact on the system varies in time.

**Exhibit 5** **Polarization Mode Dispersion (PMD) in Fiber**




PMD is more capricious than predictable, and is very dependent on the qualities of the fiber. According to Telcordia test results, PMD can depend on a range of variables:

- Cable age or vintage
- Temperature of cable
- Cable design
- Cable manufacturer
- Plant type

Using conventional approaches to 40G (or 100G), there is no good remedy to PMD other than fiber plant upgrade. Some in the industry are ready to propose that active optical PMD compensators be deployed in front of all 40G receivers—the effectiveness of these devices still needs to be demonstrated.

## C. Fiber Quality as a Barrier to Deploying 40G

As we described above, a number of physical properties of light traveling in a glass fiber medium are negatively affected by speeding up the light from 10G to 40G (and 100G). In this section, we collect a number of observations from carriers and others about the quality of fiber deployed, and the appropriateness of running 40G on fiber that now carries 10G. It is a generally accepted industry rule of thumb that about 30% of deployed fibers cannot handle 10G (using TDM binary modulation), and this means that an even higher percentage will not be able to handle 40G without suitable mitigation remedies.

T-Systems, the systems and network integration unit of Deutsche Telekom (DT), published the results in 2007 of its detailed study of DT's backbone network concluded that:

> "…less than 50% of the routes can be used for 40G," and solution options include "detect and remove dominating high-PMD cable segments or using robust WDM (e.g., low baud rate techniques)."
>
> [T-Systems from OFC/NFOEC-2007 Workshop "40Gb/s Networks and the PMD Challenge"]

It is not necessarily just older fibers that cannot handle high capacity optics. At this point, it is helpful to know of a key PMD metric. A PMD coefficient expressed in ps/√km (picoseconds of PMD delay divided by the square root of the span length) is used to measure the suitability of fiber at various distances, and a 0.5 ps/√km rating is what many use to indicate that the fiber can handle 10G with reasonable PMD. In FiberWork's 2005 study of Brazil's fiber installed between 1997 and 2002 (in all types of service providers), it was found that:

> "19% of the surveyed installed cabled fibers present PMD coefficients equal or higher than 0.5 ps/√km and, therefore, do not comply with the requirements of current transmission technologies such as 10Gb/s systems. By conducting a per-route balanced analysis of the same data, the outcome becomes worse, with 30% of the route fibers presenting PMD coefficients equal or higher than 0.5 ps/√km. This audit also reveals that 18% (or 39% when a per-route balanced analysis is concerned) of the actual concatenated spans will not comply with the 40G/s technology."
>
> [S. Barcelos, et al., paper NThC3 NFOEC 2005]

This study audited only fibers installed n Brazil, but since a reasonable amount of the fibers and cables were manufactured elsewhere in the world, the FiberWork PMD audit can be seen as a sample of fiber installed between 1997 and 2002 in other world regions.

The fiber plant PMD problem will not go away, as it is often not reasonable to install the latest PMD tolerant fiber on any route that will be upgraded to 40G (or 100G). No carrier would consider such a move due to cost and elapsed time considerations, as each would impair the ability of the carrier to compete effectively. So, the answer has to come from innovation in PMD and CD compensation, amplification methods, or techniques that avoid these issues by using a 10G baud rate.

## D. Network Architecture: Keeping Line Design Intact

Service providers have planned, designed, and deployed their networks over time, responding to customer needs, changing traffic patterns, available capex, operational efficiency considerations, service flexibility, and a variety of other factors. They have a lot invested in their network designs, using direct routes, rings, and mesh topologies to fit current and future business needs.

Many WDM networks now employ ROADM equipment, leveraging longer reach 10G transponders, which together add versatility and operational efficiency, as carriers move to make WDM their prime transport layer. With this in mind, carriers do not want to be forced into the unnatural act of drastically changing these line designs in order to add the next natural progression of capacity at 40G. They certainly prefer to add 40G to their more efficient 10G networks. But to achieve this, there is a set of desired requirements:

- 40G fits into 50GHz spacing, so 40G wavelengths can go through any OADM and ROADM filters in the network
- 40G boards operate in existing 10G equipment
- 40G does not diminish reach compared to contemporary 10G reach (in terms of the end to end network or link length where regens are used or between terminal nodes)
- The number of OADMs and ROADMs allowed on a path is not reduced
- Investment in additional electrical regenerations, compensation equipment, and amplifiers is minimized
- 40G, 10G, and 2.5G in different wavelengths are on the same fiber, and 100G in the future
- Equipment is ready for 100G

This is a hard set of requirements to meet, but is the service provider's ideal.

# IV. Comparing 40G Solutions

To achieve 40G, new modulation schemes and approaches are being developed. Data is encoded onto any medium—copper, fiber, air—using a simple scheme, most often representing a 1 or 0 in some manner. Modulation techniques are used to encode data onto light traveling through glass fiber. Each technique attempts to minimize the various impairments while minimizing the cost of the equipment.

In this chapter we will cover the advantages and disadvantages of 4 main modulation schemes being used or considered for 40G (and for 100G). These schemes are Duo-Binary, DPSK, DQPSK, DP QPSK, the relative performance metrics of which are summarized and compared to 10G NRZ as a reference in Exhibit 6.

**Exhibit 6** **Modulation Scheme Comparison Summary**

| | 10G NRZ | Duo-Binary | DPSK | DQPSK | DP QPSK |
|---|---|---|---|---|---|
| Baud period (symbol period) | 100ps | 25ps | 25ps | 50ps | 100ps |
| Symbols per baud | 1 | 1 | 1 | 2 | 4 |
| Effect on reach | 100% | Reduce 60% | Reduce 60% | Reduce 35% | 100% |
| PMD tolerance: DGD | 15ps | 3.5ps | 3.5ps | 8ps | 8–25, depending on DC method |
| CD tolerance in ps/nm | +/- 500 | Much lower | Much lower | Lower | Lower to much better, depending on DC method |
| 100GHz fiber tolerance, #OADM/ROADMs traversed | >16 | 8 | 8 | >8 | >16 |
| 50GHz filter tolerance, #OADM/ROADMs traversed | >16 | 3 | 3 | 8 | >16 |

A short description of each modulation is presented below:

- **Duo-Binary or PSBT (Phase Shaped Binary Transmission)** uses the phase property of light to do the encoding, and needs only half the signal power to transmit a given amount of data compared to standard NRZ signals; reducing the signal power has the advantage of better tolerance for CD and PMD
- **DPSK (Differential Phase Shift Keying)** also uses the phase property of light, and encodes the data into phase; DPSK is superior to Duo-Binary, in that reach is doubled; the PSK and its cousin, QPSK, are more tolerant to CD and produce a better OSNR signal, which are reasons to consider them for 40G and 100G
- **DQPSK (Differential Quadrature Phase Shift Keying)** is a quad-level version of DPSK, in that 2 bits are encoded at once , giving 4 combinations, and thus "quadrature;" this coding makes the baud rate half that of 40G; as an improvement to DPSK, DQPSK has lower signal bandwidth and resultant better tolerance to CD and PMD, as seen in Exhibit 6 above; compared to 40G TDM solutions, DQPSK has better tolerance to PMD; this comes at a cost in the complexity of the receiver
- **DP QPSK (Dual Polarization Quadrature Phase Shift Keying) or Polarization Multiplexed QPSK** improves on DQPSK, essentially by encoding 2 QPSK signals onto the same optical carrier; each QPSK signal operates at 10Gbaud, so the impairments behave like it is a 10G signal; using this technique, a number of 10G components can be used here, helping keep the cost closer to that of 10G system; a DP QPSK system requires a coherent receiver; coherent receivers are common in radio network equipment, but the implementation of an optical equivalent has posed several technical challenges; recent breakthroughs in DSP capabilities enable the cost effective design of such a receiver

Service providers are examining these options and variants, though most in the industry consider Duo-Binary to be the least viable. Given that the equipment is robust and the price is right, carriers need to look at how each method affects their current network and future design. Such considerations include whether the 40G technology can fit through 50GHz spacing, whether the current design of 4, 8, or 16 OADMs/ROADMs in mesh or rings has to be changed, and whether additional amplifiers or regens need to be inserted. There are many issues beyond the merits of the modulation scheme itself.

# V. 40G DWDM Today—Why Not 100G?

In this section, we address the issue of the duration of the 40G market. As we showed in Section I, Exhibit 3, the 40G market exists and is growing quickly, and the 100G market does not exist today. Infonetics believes the 40G market is here to stay for 8–10 years, and that 100G products will take 4–5 years to achieve the status of 40G equipment today.

There are 2 basic issues to consider: arrival time of 100G equipment, and market demand for 40G.

A number of factors point to a several-year arrival span for 100G:

- The 100GE standards process currently targets mid-2010 for the industry standard; this goal is 2 years in the future as we write this paper, and most standards goals get delayed, especially when breaking new ground, like 100G is
- We will see proprietary 100G products on the market perhaps by the end of 2009 or early in 2010; although these will help service providers become familiar with 100G and shake out product and technology issues, Infonetics believes only a few carriers will participate in these early efforts
- It has already taken several years after demonstrating 40G and first deploying 40G in service provider networks to get to the point where a few manufacturers are supplying 40G gear; 40G pricing is still not at “mass market” levels of 2.5 X 10G gear, although there are other benefits discussed later—it is just now reaching parity of 10G pricing at 4 X 10G in some bids; the same long process will very likely occur for 100G—except in the case that a surprising technology breakthrough occurs
- Infonetics believes it will be in the 2012-2013 when manufacturer revenue for 100G equipment will equal or surpass 40G; even then, a large base of 40G will be built up, and revenue will continue for years

Market demand for 40G is now building, and it will take a few years for demand for 100G to develop:

- We hear statements from a few adventurous service providers that they would buy 100G now if it were available, but we heard similar statements when 10G was in early development; 100G is not available now; there are no routers with 100G interfaces, and fewer than 10,000 40G ports will be shipped on routers in 2008
- Though traffic is growing steadily and strongly as the video infusion grows, the market has to wait for proven, reasonably priced 100G with volume deployment technology credentials, before carriers will invest in it; carriers cannot yet measure the ability of 40G wavelengths to "soak up" the growing bandwidth, but it is quite possible that 40G will be the foundation to accommodate this traffic
- Some ask if providers can afford to wait for 100G and bypass 40G altogether; Infonetics believes the answer is no—since traffic is growing at such a rate, and the availability of 40G gear is established, there are no reasonable barriers to investing in 40G; in fact, it could be folly to wait until 2010–2011 for the early standards-based 100G gear and risk over investment in 10G gear, just to avoid 40G
- An economic factor may hinder and/or impede the 40G market—the impact of the looming US recession and its effect worldwide; the downturn/slowdown/recession could cause a lag, meaning that potential effects on bandwidth hungry services/applications will likely only be felt in 2010; this in turn could slow the market for 40G and therefore even delay further out the market for 100G; conversely, the belief that people will shift from traditional entertainment to online entertainment quicker (to reduce entertainment outlay) during this downturn may actually fuel bandwidth demand, and therefore accelerate the move to 40G, and this at the expense of the service provider, which may find it difficult to monetize this bandwidth usage

# Appendix: Checklist of 40G Purchase Considerations

In our discussions with service providers around the globe, we find some common concerns when considering the purchase of 40G optical equipment. While the very real concern about equipment price, which focuses on 40G prices compared the price of 10G gear, often generates the first topic of conversation, the stronger worry is of TCO (total cost of ownership) outlined in 3 main areas:

- Re-use of current equipment: can 40G (and 100G in the future) be accommodated in current equipment and not require the abhorred forklift upgrade?
- Use the current fiber plant, usually, but not always, the 10G routes, and not have to invest in expensive deployments of new fiber on routes
- Re-use of current line design, i.e., the effect on network architecture in terms of the numbers of OADM and ROADM nodes on any pathway in a ring or mesh.

*Equipment Cost*

1. What is cost of 40G equipment?
    - Does it cost 6-8 x 10G gear? 4-5 x 10G? Or the often sought 2.5 x 10G?
    - Equipment price is important, but it is not the only consideration, as TCO is a bigger issue
    - Full costs involve use or not of existing fiber plant
    - Can 40G be used in existing 10G equipment and network design, in volume, without adding regens and costly PMD compensators?
    - Must the architecture of existing rings and mesh be changed, or can current line design remain undisturbed? Can 40G be built on best practice 10G networks that minimize regens?

*Re-use of current equipment*

2. Can we add 40G boards into existing gear?
    - Can we use our existing WDM gear used for 10G?
    - Do we have to buy new platforms that accommodate 40G?

3. Will the same technology be used for 100G, so that 100G will work in the same equipment and network without re engineering?

*Use of current fiber plant*

4. Do we need to install new fiber for 40G?
    - Can the 40G technology run on routes carrying 10G now?
    - Can the 40G technology run on routes carrying 2.5G now?
5. How does the 40G equipment affect Polarization Mode Dispersion (PMD)
    - How tolerant of PMD is the 40G technology compared to 10G?
    - Does the 40G gear have special componentry for PMD compensation that makes it less efficient for volume deployment?
6. How does the 40G equipment deal with Chromatic Dispersion (CD)?
    - How tolerant of CD is the 40G technology compared to 10G?
    - Does the 40G technology increase CD?
    - Can 40G gear operate with no effect on CD?
    - Does the 40G gear have special componentry for CD compensation?
    - Do we need Dispersion Compensation Fiber (DCF), and a DCF map?

*Effect on current network architecture*

7. Will the 40G technology cause a change in current line/network design?
    - Can 40G work over a 4 node path? 8 nodes? 16 nodes?
    - Can we keep our current ring and mesh configurations?
    - Can we keep the same 10G reach?
8. Will the 40G equipment require additional amplifiers on any routes?
    - Do we need to add more amplifiers in the huts?
    - Will we need to add more hut sites on existing routes?
    - Can we remove some amplifiers if DCF is not required?
9. Will the 40G equipment handle 100Ghz spacing and 50GHz spacing over the same fiber?
10. Does 40G gear affect the existing cascaded OADM/ROADM nodes?
    - Can 40G work with 4 OADM/ROADM nodes on path (ring or mesh)? 8 OADM/ROADM nodes? 16?

# About Infonetics Research

Infonetics Research (www.infonetics.com) is the premier international market research and consulting firm specializing in data networking and telecom. We provide a complete view of the market through constant interaction with equipment manufacturers, service providers, end-users, chip and component manufacturers, sales channels, and the financial community. We offer quarterly market share and forecasting, end-user survey research, service provider survey research, and service provider capex analysis. We are respected in the industry for being objective and accurate and for delivering on time all the time.

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- Webinar, Conference and Event Speaking
- Custom Demand-Side and Brand Market Research
- Custom Market Size and Forecasts
- Technology and White Papers
- Competitive Analysis and Due Diligence

**Coverage Areas**

- Broadband and IPTV
- Enterprise Voice and Data
- Network Security
- Service Provider Capex
- Service Provider Optical, Metro E, Routing, and Switching
- Service Provider UC, IMS, and FMC
- Total Telecom and Datacom
- Wireless and FMC

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