Designing for Profitability in the

Physical Layer of Wireless Networks

Introduction

Growth in wireless services is increasing the number of copper and fibre cables that must be managed – causing an increased workload for reconfigurations and maintenance. Meeting the challenge of increasing profits in the face of fewer capital and operating resources to manage this steadily growing and more complex wireless network infrastructure requires improvements in operational efficiency from Network Operations. This paper discusses the proven solution for increasing operational efficiency – designing a foundation of connectivity into the physical layer that helps connect, protect and manage cables without disrupting service.

Who is the Customer?

Ever since the word "quality" entered the language of business, there have been many methods developed for improving quality. Not to be confused with QoS, corporate quality programs are instituted to improve organisation performance – and provide profits. There are many quality programs available today. There is also a thread woven through all of these different programs, as follows: first, recognise your customers, and second, meet the needs of your customers.

Given the challenges facing wireless service providers today, a focus on quality – and profits – is more important than ever. These challenges include limited capital and operating dollars, shrinking ARPU, and churn coupled with pressure to upgrade and grow the network to handle demand for enhanced services. For wireless service providers, focusing on quality and improving profits starts with serving the needs of both internal and external customers.

By recommending and delivering advanced capabilities for the network, the Network Planning organisation has an important impact upon meeting the needs of subscribers – the external customers. Too often, however, network planning occurs with little or no attention paid to Network Operations – the internal customer for Planning. This internal customer/supplier relationship (see Figure 1) exists because Network Planning (with Construction) is responsible for handing off the network to Operations for ongoing management. The service provider can never meet the full expectations of subscribers if the needs of Operations, with its own set of measurements and benchmarks, are ignored (see Figure 2). Realisation of this customer/supplier relationship within the service provider organisation provides Planning with important direction for physical layer architecture.

Quality measures for Operations are well defined: time to repair, circuit availability (99.999%), and technician productivity, among others – all of which boil down to operational efficiency. In a customer/supplier relationship, these measures are among the most important factors that Network Planning should take into account in network design. Planning a network without consideration of these measures actually thwarts the overall goals of the wireless provider – to deliver cost-effective, always available, high quality services.

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Operations: The Custodians of Evolving Networks

Wireless networks are in constant change. Reconfiguring circuits. Adding cards, elements, and circuits. Upgrading software and hardware. Integrating new elements with old elements. Not to mention routine maintenance and troubleshooting of a steadily growing network infrastructure.

Clearly, the physical layer of the wireless network is getting larger and more complex. With more wireless data services come smaller coverage areas, increasing the number of cell sites as well as the number of copper and fibre cables in the network. The constant change of reconfigurations and maintenance in the network is conducted largely by Operations – a huge workload that has a direct impact on the profitability of the service provider.

Profitably managing constant change requires certain characteristics in the physical layer. To meet objectives of a more reliable, more available network – often with the same or fewer resources – Operations requires a network infrastructure that enables:

- Rapid and transparent changes to the network
- Non-intrusive testing and monitoring of circuits
- Fast and accurate fault isolation
- Quick circuit rerouting options
- A common physical layer interface and methodology for craft

Simple termination panels are not the answer. Neither are lowest purchase-price solutions, transport-rate performance monitors, nor shortcuts that ignore design of cable routing paths. By designing a foundation of connectivity for the physical layer, the Network Planning organisation not only meets the requirements of its internal customer – Operations – but also contributes to the profitability of the company as a whole.

Supplier	Customer(s)
Vendors (i.e., ADC)	• Network Planning • Network Operations • Subscribers
Network Planning	• Network Operations • Subscribers
Network Operations	• Subscribers

Figure 1. Defining the Customer/Supplier Relationship

Customer	Measures
Network Planning	• Boost network performance • Increase available bandwidth • Support revenue growth with new features and services • Speed time of deployment • Improve ROI
Network Operations	• Decrease time to repair • Improve circuit availability (99.999%) • Increase technician productivity
Subscribers	• Cost effective services • Always available services • High quality services

Figure 2. Critical Measures for External and Internal Customers

Foundation of Connectivity – Design for Craft Efficiency

The wireless physical layer is destined to be a hybrid network for the foreseeable future. Circuit-switched equipment will reside with packet-switched electronics. Coax and twisted pair cables will coexist with a growing number of fibre cables. Electronics from multiple vendors will populate racks and cabinets as base station controller (BSC) sites and mobile switching centers (MSC) grow with a steady rise in wireless data traffic. As a result, Operations has to install, test, and reconfigure multiple types of equipment from multiple vendors.

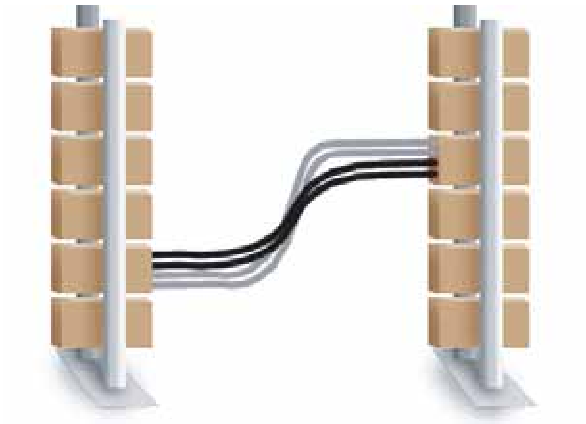
And today, Operations – like everyone else – is being asked to do more with less. For Operations to meet their metrics of increased network availability, shortened time to repair, and increased productivity, the burgeoning wireless physical layer needs to be designed for craft efficiency.

With a proper foundation of connectivity, craft practices are centralised around a common set of connectivity interfaces that remain constant despite changing technologies. Technicians conduct reconfigurations on the common connectivity work interface instead of on the backplanes of active equipment. As a result, technicians are able to accomplish day-to-day tasks faster, with fewer training hours, and with far less disruption to the network.

Creating the proper connectivity foundation starts with network design – where smart network planners design the physical layer for operational efficiency. In BSCs and MSCs, there are three ways for connecting equipment: direct connect, interconnect, and cross-connect. Making the right upfront design choices largely determines whether Operations can actually increase productivity, reduce time to repair, and increase network availability.

Direct Connect – Cheap Today, Costly Tomorrow

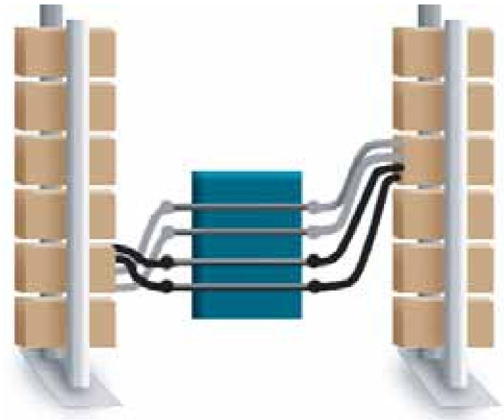
With this method, network elements are "hard wired" together with no centralised termination, patching, and cable management system. Yet the advantage of lower upfront costs is quickly eclipsed by service disruptions and inordinate operations costs as new elements are added and cables are reconfigured. With direct connect, technicians work on active equipment, making operations much more cumbersome and expensive. Simple maintenance and reconfigurations require taking circuits out of service, working on sensitive backplanes, and re-terminating and testing equipment cables. A connectivity foundation, whether an interconnect or cross-connect design, typically equates to 1% to 3% of the cost to deliver a circuit, a small price to pay in comparison to the costs of churn, lost revenue, and increased labor costs.



Direct Connect

Interconnect – Better, if Changes are Minimal

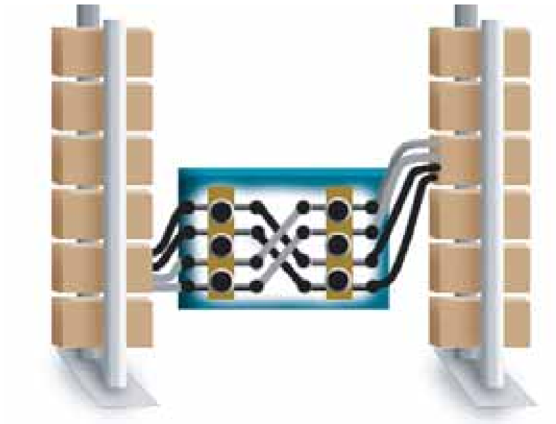
In an interconnect design, outside plant cables are terminated on the rear and equipment patch cords terminate on the front of connector panels. While presenting an improvement over direct connect, interconnect shows its weaknesses as the volume of rearrangements, upgrades, and addition of new elements increases. Without dedicated ports on the equipment side of panels, reconfigurations are difficult, especially as distance increases between the interconnect bay and active equipment. Labeling and record keeping of equipment cables is difficult, too, making identification and tracing of circuits awkward. Typically, interconnect systems offer poor cable management, especially in storage of equipment patch cord slack. Reconfigurations force technicians to work with equipment cables, raising the chance of disrupting service.



Interconnect

Cross-connect – Designed for Operational Efficiency

A cross-connect architecture provides the greatest flexibility for reconfigurations and greatest efficiency in craft practice. All outside plant cables and equipment patch cords are connected to the rear of the frame or bay and, once terminated and tested, never have to be touched again. All reconfigurations occur on the front of the bay or frame using cross-connect patch cords. With a cross-connect design, equipment patch cords and OSP cables are less vulnerable to damage during rearrangements and routine maintenance, emergency service restoration is simplified, and easier access to network elements through simple patching greatly increases technician efficiency. This craft friendly design supports cost-effective growth and change in the physical layer.


Cross-connect

Foundation of Connectivity – Increasing Profits through Operations

Connectivity is more than a set of discrete products for terminating cables. On the contrary, proper connectivity is a design philosophy combined with highly functional products for terminating, patching, accessing, and managing cables. Creating a foundation of connectivity for the physical layer facilitates growth and change without disrupting service – yielding operational efficiency that reduces costs, improves network reliability, and contributes to profit improvement.

A foundation of connectivity helps connect, protect, and manage cables within BSCs, MSCs, and cell sites using products and techniques that are field proven in carrier operations around the world. These designs offer more reliable connections and add density that delays capital expenditure for additional floor space. The design criteria for a proper foundation of connectivity include the following:

- Create a cable management platform that provides bend radius protection, smart cable routing paths, functional access to cables, and both on-frame and off-frame physical protection for cables
- Place passive monitoring ports at all critical junctions of the network
- Create craft efficiency by providing a standard technical interface

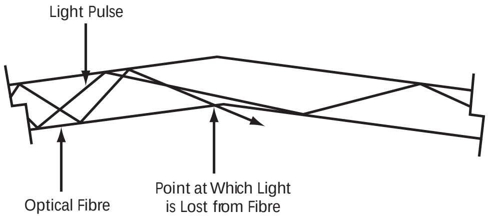
Cable Management – The Basics of a Connectivity Foundation

Evolving the wireless network to deliver new, higher speed services is causing a proliferation of cell sites, requiring many more copper and fibre cables in and around MSCs and BSCs. Yet with all of the high tech radios, mobility and control servers, gateways, and other electronics, cables and connectors are generally the last item that anyone thinks about. In reality, poorly managed and unprotected cables are more likely to bend and break, cause service failures, and increase network operations costs through unnecessary dispatches, repairs, and replacements.

On the surface, cable management is a bit unglamorous – connectors, cables, slack managers, troughs, and storage trays. These simple components really don’t fit into buckets of “technology” or “capability” usually coveted by network planners. Yet it is precisely these relatively inexpensive components of the network that can have long-term, positive impact on the reliability and profitability of the network.

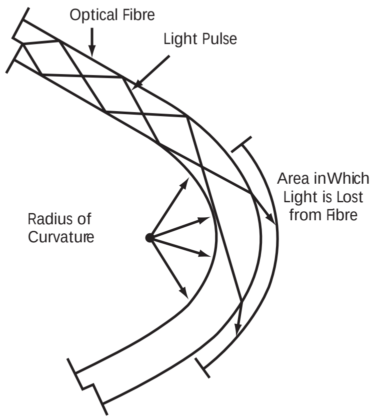
Bend Radius Protection

The must-have of proper cable management is careful attention to the bend radius of cables. For copper cables, improper bend radius or routing over sharp edges leads to cable fatigue or severed cable that disrupts service. If fibre cables are bent beyond minimum bend radius levels, insertion loss is added that reduces performance of fibre cable. Fibre cables, of course, are much more susceptible to breakage, making careful attention to bend radius requirements an essential part of network design.



Microbend

As more and more fibres are introduced into the physical layer, even simple upgrades can become a costly service problem. If there are unprotected bends in routing paths, adding new fibres on top of existing fibres can greatly increase the pressure on existing fibres. As a result, fibres that have performed fine for years start showing increased attenuation and, eventually, complete failure. The proper cable management system provides bend radius protection at all points where fibres make a bend, including: troughs or raceways where fibres enter and exit frames or panels; at connectors; in the upper and lower troughs on a frame; within a panel, storage area, or splice tray. As a design objective, protecting the bend radius of cables is fundamental to increasing circuit availability and reducing repair calls on Operations.

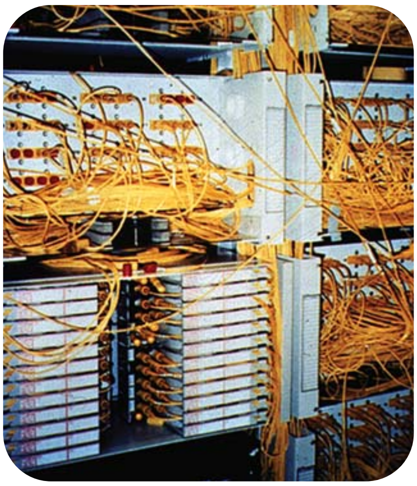


Macrobend

Cable Routing Paths

Creating a reliable, low-maintenance cabling infrastructure for the long-term depends upon proper routing of cables throughout MSCs and BSCs. For fibre cables, one of the most common causes of bend radius violations – and disrupted service – is improper routing of cables. Routing paths that are clearly defined and easy to follow alleviate congestion in termination panels, troughs, and raceways, reducing bend radius violations and reducing insertion loss problems and long-term failure – all of which contribute to increased availability of services to subscribers.

Clearly defined cable routing paths



Undefined cable routing paths

Proper cable routing is an upfront, design-stage task. For example, in a well-defined fibre cable routing scenario, a downspout from an overhead trough system is positioned directly over the vertical cable guide on a fibre frame, eliminating the possibility that fibres from that downspout can be routed incorrectly into an interbay management panel. In another example, proper cable routing reduces cable pile-up in troughs and raceways and enables technicians to easily trace and remove jumpers and cross-connect cables when equipment is upgraded or removed – the weight of which can impede cable performance and service availability.

Leaving cable routing decisions to chance presents risk to the long-term reliability and efficiency of the network. Cable routing paths help Operations increase productivity by reducing both training time and the time required for reconfigurations of cables and patch cords. Pre-defined, well-defined cable routing paths greatly improve the uniformity of work and compress the time required to turn-up service, shortening time to revenue for new network assets.

Cable Access

A propagation of new terminations and cables in BSCs and MSCs to support growing wireless voice and enhanced data services makes access to cables another important, upfront design issue. Proper access ensures that any cable can be installed or removed without causing damage or service disruption to adjacent circuits – an attribute that is especially critical in highly dense frames and panels. Proper access also means technicians have ready access to transmit and receive signals on any piece of active equipment at any time, without use of special tools. With proper access a simple line card reconfiguration can take just minutes instead of hours. A physical layer with proper access will have a lower operating cost and improved reliability.

The impact of proper cable access can is evident in fibre connector cleaning. Dirty connectors are the leading cause of poor fibre performance and the most likely failure points in the network, making periodic cleaning of connectors essential. Even the smallest dust particle on fibre endfaces can cause high insertion loss, causing more technician time on troubleshooting circuits while inhibiting network performance.

Access is more than just room to work and inspect fibres for tiny particles and fingerprints. Proper access actually plays a role in keeping dirt and debris away from connectors. Fibre access in a proper connectivity solution includes adapters with removable retainers that enable access to individual, not multiple, connectors. This design allows a technician to remove the connector, clean it, and put it back without exposing other fibres to dirt and possible damage from unneeded handling.

Removable retainers enable single circuit access

Physical Protection

Exposed cables – extra fibre jumper lengths on the floor, unmanaged patch cord slack, or cables laid haphazardly on ladder racks – are susceptible to damage that can cause outages, increase expenses, and thoroughly annoy subscribers.

In a well-designed physical layer, panels and frames include bend radius protected storage for cables and patch cords. Fibre storage may be integrated with a splice tray or fibre termination panel, or installed as separate modules in frames. For Ethernet connections in a cross-connect design, proper cable storage ensures that equipment cables are never exposed to the day-to-day work of technicians.

Dangling or loose cables are accidents waiting to happen. A proper connectivity foundation eliminates accidental damage to cables with integrated physical protection that not only reduces unnecessary outages but also lowers operations costs by reducing the volume of unneeded repairs.

Non-intrusive Testing and Monitoring for Proactive Maintenance

Maintaining the health of the network is the prime responsibility of Operations. As e-mail and other data services become more widespread wireless service offerings, extended signal loss or downtime will be unacceptable to subscribers. Finding a problem before it becomes a hard failure becomes an important service objective for Operations. This proactive approach to network management also affords Operations the flexibility to choose the best time and way to address uncovered network problems.

Proactive maintenance practices require a connectivity foundation that provides test access points at demarcation, handoff, and other critical points in BSCs and MSCs. These passive test points allow technicians access to both directions of a signal without disrupting service. Unlike performance monitoring features of some active equipment, which can only report on the transport rate of a circuit, passive test points enable technicians to check periodically if power levels are deviating from the norm or bit-error rates are increasing, sure signs on a fibre circuit that a laser, connector, splice, or other network device is deteriorating. Passive test points also eliminate the risk of damaging active electronics or adjacent circuits, problems frequently encountered with "built-in" test points on cards and other network elements.

As traffic increases, service providers will take advantage of Wave Division Multiplexing (WDM) to double the bandwidth of existing fibres. WDM modules can also provide non-intrusive, out-of-band testing that enables circuits to operate and test at different wavelengths. Fibre circuits operating at 1310 nm can be tested at 1550 nm; fibres operating at 1550 nm can be tested at 1625 nm. With WDM modules at each end of a circuit, technicians can also conduct full bi-directional testing – eliminating a truck roll, or two, at the far end and without disrupting service.

Establishing an open platform of passive test points throughout the network yields additional operational savings for service providers. As the network grows more complex, a variety of active equipment is deployed – each with its own proprietary software and testing protocols. With a common platform of passive test points, technicians are able to test any brand of active equipment in the network with only one test box. This not only saves time in monitoring and testing, but also reduces technicians training requirements on multiple vendor-specific pieces of equipment.

Passive access points in the network greatly support efficiency in craft practices. For example, after rerouting a circuit at the cross-connect in just seconds, the technician can then monitor the circuit that is out of service for debug and testing purposes. For software and equipment upgrades, the technician can verify during testing and system turn-up that everything is working properly before making the circuit available to subscribers. The ability to isolate nodes, elements, and network segments with a system of passive test points is an important productivity tool for Operations.

For fault isolation alone, positioning passive test points throughout the network is another essential part of a connectivity foundation. There are handoffs to other service providers, collocation agreements, and network sharing to manage. There are content providers that will choose to blame service providers when subscribers don't pay their invoice. And there are regulations in some countries forcing incumbent wireless carriers to grant competitive access to the network. Clearly, the ability to sectionalise and localise trouble makes it easy to quickly pinpoint fault and settle disputes.

Conclusion

Bypassing the needs of Operations in design of the physical layer is a formula for higher costs and poor network performance that invites churn and reduces profits. In designing the physical layer, Network Planning must pay attention to the needs of both external customers (subscribers) and the internal customer (Network Operations).

In the face of flat revenues, high debt, and uncertainty about the future, an important path to profitability is reducing costs. That is why improving operational efficiency is so important. Adding proper connectivity does add cost to a project, as little as 1% to 3% of total project costs. However, the payback is tangible through improved operational efficiency. In real terms, operational efficiency means the following:

- Technicians resolve more troubles/notices per month
- Reconfigurations take minutes instead of hours
- Problem circuits are detected and rerouted before service is affected
- Hardware and software upgrades are installed, tested, and debugged quicker without disrupting service
- Integrating new network elements with the existing plant is seamless
- Routine maintenance is easier and faster to perform

In real terms, operational efficiency equates to improved profits.

With a foundation of connectivity designed into the physical layer, Operations is able to simultaneously decrease time to repair, improve network availability, and increase craft productivity even while the network grows and changes. Clearly, every department within the wireless service provider helps to meet subscriber needs – new cell sites improve coverage, new data services boost revenue, and new air modulation techniques maximise available spectrum. However, meeting the needs of subscribers – cost-effective, always available, high quality services – requires much more than just new technologies and increased bandwidth. Meeting the needs of subscribers requires meeting the needs of Operations by designing and implementing the physical layer with a foundation of connectivity.

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