Pseudo-Wires: 
A Full-Service Solution for Mobile Backhaul

WHITE PAPER
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Executive Summary

The mobile market is growing at an extraordinary rate fueled by increased voice usage and particularly by demand for mobile data services. To keep up with the demand and to enable revenue growth, service providers continue to expand their coverage and upgrade their services from 2G to 2.5G, 3G and 4G, with early deployments of HSDPA/HSUPA (HSPA) already under way.

In today’s difficult economic times, service providers must not only focus on meeting the increased demand, they must also be concerned with the return on investment (ROI) for capital expenditures. As networks are expanded and upgraded, service providers must focus on leveraging existing infrastructures and reducing operating expenses, especially recurring costs, in order to maximize ROI. The radio access network (RAN) in particular, where T1/E1 lines are often leased from the incumbent PTT or local exchange carrier (LEC), is a source of high recurrent costs for wireless operators. It has been estimated that backhaul transmission costs can amount to as much as 40% to 60% of network OpEx, especially in 3G networks. According to Yankee Group, wireless operators annually spend approximately $22 billion globally to lease backhaul transmission.

Recurring costs in the RAN are exacerbated by deployments that are best characterized as multiple overlay networks. These overlay networks consist of a variety of backhaul transport techniques and technologies resulting from multiple standards, multiple vendors’ equipment, or previous mergers and acquisitions. As new 2.5 and 3G networks are implemented and operators get prepared for 4G, these overlay networks in the RAN multiply overall operating costs. In addition to the cost of operating overlay networks while migrating from one generation to the next, the cost problem is multiplied for some providers by their migration from TDMA and/or CDMA to GSM/UMTS/LTE architectures.

Axerra Networks’ Pseudo-Wire technology offers a full-service solution for mobile operators. Axerra Networks’ solution reduces backhaul expenses by providing an alternative to costly leased-line access, enabling backhaul for all generations of voice and data traffic over Carrier Ethernet, xDSL, EPON/GPON, cable HFC, and broadband packet radio (including WiMAX). In addition, Axerra's Pseudo-Wire solution provides the ability to combine voice and data services from multiple protocols, enabling mobile providers to leverage existing equipment, optimize the RAN, and significantly reduce the expenses associated with backhaul transmission. These capabilities translate into immediate and significant cost savings, thereby enhancing mobile operators’ profitability today.
Introduction

Global Growth in the Mobile Market

The mobile market is growing at an extraordinary rate. This growth is fueled by ever-increasing voice and data usage. A growing reliance on mobile phones (smartphones) for business and social communication is a major factor increasing the demand for data services. Among the applications driving demand for data services in both the business and consumer segments of the marketplace are mobile video, content engines, social networking, downloadable ring-tones, images (camera phones), games, news and information sources, mobile chat, and Internet access.

Explosive worldwide growth is placing greater demand on wireless networks and supporting platforms. To enable many of the new mobile data services that offer additional revenue opportunities for providers, increased bit rates and greater network capacity are required. Network technologies are evolving to meet this need.

Network Evolution

The ongoing evolution of 3G services includes technologies such as HSDPA (High Speed Downlink Packet Access), HSUPA (High Speed Uplink Packet Access), DVB (Digital Video Broadcasting) / DAB (Digital Audio Broadcasting) and LTE (Long Term Evolution). HSPA and LTE are especially important because they offer the high quality and capacity needed to handle the emerging data-intensive applications discussed above, and are already becoming important considerations when designing mobile network architectures.

The growing demand for new services and the continued evolution of network architectures are providing mobile operators with additional opportunities for revenue growth, but are also posing significant new challenges.

Challenges of the Mobile Market:

The Impact of New Services in the Radio Access Network

Each new generation of services provides new capabilities, but also requires more bandwidth – both for the air interface and in the radio access network (RAN), sometimes referred to as the backhaul network. Figure 1 (see next page) shows bandwidth requirements increasing as GSM technology and services evolve.

Capital investment for network upgrades to support the new services represents only a part of the cost of doing business for operators. The migration, especially to support new data services like HSPA, also involves additional backhaul expenses. Whereas capital equipment and spectrum licenses are one-time expenses or fixed costs, ongoing backhaul expense in the RAN is a wholly different matter – a constant and increasing expense. As more services and more subscribers are added, bandwidth requirements increase and so do the backhaul costs. Optimizing RANs to address the growing and dynamic nature of today’s traffic, while simultaneously reducing backhaul expenses, is becoming more important than ever before.
The Need to Reduce Backhaul Expenses

Backhaul has always been a source of high recurrent costs for wireless operators. According to Yankee Group, wireless operators annually spend approximately $22 billion globally to lease transmission backhaul. It has also been estimated that backhaul transmission costs can amount to as much as 40% of network OpEx in 2G networks, and 60% or more in 3G.

Today’s RAN backhaul network, is made up of TDM-based leased lines for the backhaul of traffic from base stations to the base station controller (BSC), which then connect to the mobile switching center (MSC) and PSTN. Traditionally, mobile operators have leased T1/E1 lines from the incumbent PTT or LEC. The cost for these T1/E1 lines varies greatly, but is always a significant component of total OpEx. A single T1/E1 typically costs between $200 and $800 per month, but can vary greatly depending on a variety of factors. This is typical of today’s base stations, where backhaul requirements are in the 1-4 T1/E1 range in non-dense areas and 4-8 T1/E1 in dense areas and expected to grow even more in the near future. At many base stations, the bandwidth requirements of HSPA are pushing beyond what can realistically be achieved using today’s T1/E1 leased lines.

Operating costs in the RAN are also impacted by the expense of overlay networks. Mergers and acquisitions within the service provider industry, together with multiple standards and multiple, often incompatible, vendor equipment, have all resulted in overlay networks. There are as many as three different base stations that have been deployed at some cell sites: GSM to provide voice and low-speed data, EDGE to provide high-speed data, and UMTS to provide very high-speed data. Not only are different generations of equipment used in these overlay networks, but different generations of 2G, 2.5G, and 3G traffic each utilize their own T1/E1 leased lines. Consequently, each of these T1/E1s is often partially filled, resulting in expensive inefficiencies.

These inefficiencies are a direct result of the static-mapping nature of TDM transport – there is no way to dynamically move capacity from one base station to another (i.e. voice to high-speed data) even within the same cell site. What’s more, the TDM bandwidth is dedicated on a point-to-point basis from each base station all the way back to the BSC/RNC. Additional backhaul expense results from unused bandwidth that is often stranded in the “wrong place at the wrong time.”
The Emergence of Packet Access Technologies

The need in the RAN for modern transport technologies that are better suited to bandwidth-hungry data services and that can furnish better flexibility and economies of scale has started to be recognized. In the GSM architecture the UMTS standard already incorporates ATM with IMA as an interface for the NodeB (the UMTS equivalent of the BTS). However, traffic from these ATM interfaces is typically backhauled over point-to-point E1 or T1 leased lines. In both Europe and North America, ATM transport networks are occasionally used for backhaul transport.

But the continued evolution of mobile services is toward technologies that are intrinsically packet-oriented, such as HSPA, and indicative that packet access networks, rather than TDM-based T1s and E1s, are the logical transport for backhaul in the RAN. A number of technologies that are cost-effective and provide flexible, high-capacity backhaul transport are emerging as the front-runners for next generation packet access networks. These technologies include Carrier Ethernet (also known as Metro Ethernet or Optical Ethernet), xDSL, cable HFC, EPON/GPON, and broadband packet radio (including WiMAX).

The Case for RAN over Packet Access

The savings in operating expense are readily seen in a typical example. In this example, the mobile operator needs to deploy HSPA in 500 cell sites of a medium-sized metropolitan area. The table below shows the current cost structure with only 4 E1s per site. However, these operating costs are likely to double with HSPA, which can easily require 8 E1 lines or more. With E1 lines typically costing between $200 and $800 per month, this example assumes an average cost of $300 per E1. In comparison, a typical Carrier Ethernet service costs just $40 per Mbps each month. So, a monthly charge for the capacity equivalent of four E1s (8 Mbps) only amounts to $320 rather than $1200.

<table>
<thead>
<tr>
<th></th>
<th>Current Cost Structure</th>
<th>RANoP Cost Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td># Cell Sites for Mid-Size City</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td># E1’s required per cell site</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td># Ethernet interfaces per cell site</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cost per E1 per month</td>
<td>$300</td>
<td>$0</td>
</tr>
<tr>
<td>Ethernet cost per month (8Mbps eqv to 4 E1)</td>
<td>$0</td>
<td>$320</td>
</tr>
<tr>
<td>Monthly Cost</td>
<td>$600,000</td>
<td>$160,000</td>
</tr>
<tr>
<td>Yearly Cost</td>
<td>$7,200,000</td>
<td>$1,920,000</td>
</tr>
<tr>
<td>Savings per annum (dollars)</td>
<td>$0</td>
<td>$5,280,000</td>
</tr>
<tr>
<td>RANoP cost advantage</td>
<td>0%</td>
<td>73%</td>
</tr>
</tbody>
</table>

While this is only one example, it vividly illustrates the fact that using packet access in the RAN can reduce an operator’s backhaul charges by over 70%. Put into context, with backhaul accounting for 50% to 60% of all OpEx costs, a 70% reduction in backhaul charges represents a 40% decrease in overall OpEx, which is very significant indeed.
In absolute numbers, the quantity of dollars saved (which flows straight to the bottom line) continues to increase as the bandwidth requirements of each cell site increase. The quantity saved also will increase as more cell sites are added to support UMTS and HSPA because 3G base stations cover a smaller footprint than 2G base stations.

In addition to providing lower operating expense while furnishing flexible, high capacity transport, these packet access technologies offer a number of other benefits:

- Equipment costs are significantly lower than legacy equipment costs.
- Significant economies of scale can be achieved with a unified network, not only for mobile voice and data services, but also wire line business services.

In addition, provisioning costs are less and do not require equipment upgrades. While continuing to add E1s to furnish projected requirements of 25-30 Mbps is an unsustainable paradigm, Carrier Ethernet, for example, offers a wide range of speeds up to 1 Gbps, in increments as small as 1 Mbps, that can be provisioned on-demand or even by the operator through a web-based tool.

**Pseudo-Wires Meet the Challenge**

The challenge has been how to support the continuing migration to 2.5, 3G and 4G architectures by transporting both voice and data traffic over packet-access networks. Pseudo-Wires (PW) are the powerful enabling technology that meets this challenge. An early innovator of Pseudo-Wire technology, Axerra Networks offers a full-service Pseudo-Wire solution for mobile operators that have been proven in field trials and live deployments on four continents. Axerra's Pseudo-Wire solution not only enables mobile operators to use packet access networks, it also gives operators a wide choice among the multiple packet network technologies that are available. Additionally, the PW solution uniquely combines circuit emulation and service emulation (TDM plus HDLC, Frame Relay, and the ATM needed for 3G UMTS) as well as Ethernet switching to enable backhaul of any combination of 2G, 2.5G, 3G and Ethernet enabled base stations voice and data traffic, all over a single packet RAN. Axerra's PW solution is also the only solution to meet the demanding quality, latency, and clocking/synchronization requirements needed for reliable backhaul of mobile services.

Axerra Networks' full-service Pseudo-Wire solution enables all generations of both voice and data over packet-access networks, enabling mobile providers to immediately profit from significant OpEx savings.

**PW Solution for Optimizing Radio Access Networks & Reducing OpEx:**

**Pseudo-Wire Capabilities in the RAN**

Axerra Networks’ Pseudo-Wire solution provides a full-service alternative to TDM backhaul using Pseudo-Wire technology. The term “Pseudo-Wire” comes from the IETF’s Pseudo Wire Emulation Edge-to-Edge (PWE3) working group, which is defining various types of Pseudo-Wires to emulate traditional and emerging services over packet networks.

Axerra has implemented the broadest range of Pseudo-Wire capabilities that enable both circuit emulation and service emulation. Circuit Emulation Pseudo-Wires (CES-PWs) furnish transparent emulation of TDM services, including both payload and synchronization. Service emulation
furnishes transport for frame-based and cell-based traffic, offering network capacity gains provided by statistical multiplexing.

Axerra’s full-service solution is comprised of both access devices and gateways. The AXN1 and AXN10 are flexible, compact AXN Pseudo-Wire Access Devices™ that are optimally sized for BTS and NodeB applications, with options supporting 1, 2, 4 and 8 T1/E1s. The AXN1600 and AXN800 Pseudo-Wire Gateways™ are modular, carrier-class platforms with the port density and resiliency needed in BSC/RNC and MSC applications. Each of these devices enables a complete range of Pseudo-Wire capabilities including Circuit Emulation Service (CES), Frame Relay, HDLC, ATM Pseudo-Wires (critical for UMTS applications) as well as Ethernet switching.

![Figure 2: Typical AXN deployment in the RAN](image)

Figure 2 shows a typical AXN Pseudo-Wire deployment in the RAN. Axerra’s AXN1 and AXN10 Pseudo-Wire Access Devices are deployed at the cell sites where they perform Pseudo-Wire adaptation (circuit emulation and/or service emulation) of mobile voice and data traffic for transport over the packet network to the BSC/RNC site. Axerra’s AXN1600 or AXN800 Pseudo-Wire Gateways are deployed at the BSC/RNC or MSC, where they terminate the Pseudo-Wire services and function as gateways to existing voice switches, the PSTN, and FR/ATM or IP/Ethernet data networks.

At the cell sites, the AXN1 and AXN10 access devices interface with the existing BTS/NodeB equipment using T1/E1 ports. Each port can be soft-configured for circuit emulation for voice transport or service emulation to transport frame-based data services or frame-based voice. In addition, AXN access devices offer unique T1/E1 interfaces that support the ATM traffic used in today’s UMTS deployments. All AXN access devices also provide customer-facing Ethernet interfaces for future services and connectivity needs.

At the BSC/RNC site, the AXN1600 and AXN800 offer not only T1/E1 ports for interfacing to legacy equipment, but also channelized DS3 and OC-3/STM-1 interfaces to connect with existing TDM-based voice switches. In UMTS applications, the ATM Pseudo-Wires (that originated as T1/E1s from the NodeB) are transported across the packet network and then consolidated in the
The AXN gateway into ATM streams on OC-3c/STM-1 interfaces to connect with the RNC. The AXN gateway also furnishes Gigabit Ethernet interfaces to hand-off data services to the RNC.

**Benefits of Axerra Pseudo-Wires**

*Any Packet Network*

Pseudo-Wires are the enabling technology for transporting mobile voice and data traffic over new high-capacity, lower-cost packet networks in the RAN. Axerra’s Pseudo-Wire solution not only enables mobile operators to use new packet access networks, it also gives operators a choice among multiple packet network technologies. AXN Pseudo-Wire Gateways and Access Devices enable use of Carrier Ethernet, xDSL, EPON/GPON, cable HFC, and even broadband packet radio in the RAN. In fact, Axerra’s solution is proven and carrying live, revenue-generating mobile traffic over Carrier Ethernet and broadband packet radio as well as xDSL and cable HFC.

*All Types of Mobile Traffic*

With a comprehensive array of both circuit emulation and service emulation capabilities, Axerra’s AXN Pseudo-Wire Gateways and Access Devices™ provide support for all generations of mobile services. Axerra solutions are currently carrying live, revenue-generating voice and data from CDMA, 1x-EVDO, GSM, and UMTS services. The proven flexibility to support all of these services ensures a smooth transition from one generation of service to the next, enabling all types of wireless traffic onto a single packet RAN without stranding any bandwidth.

All AXN access devices and gateways utilize a modular architecture that provides service adaptation on channelized interfaces down to the DS0 level. This enables the operator to configure any Pseudo-Wire service on any group of DS0s, including different services for groups of DS0s on a single T1/E1, DS3, or Channelized OC-3/STM-1. The result is that cell site traffic can be groomed to optimize utilization on the packet network and consolidated onto fully loaded, high-speed ports at voice switches and data switch/routers in the BSC/RNC. Most importantly, this capability allows the operator to combine voice and data services from multiple generations of mobile services and even from both TDMA and GSM architectures – all onto a unified packet-access network. As users transition from one architecture or service to the next, network capacity is not stranded. In fact, adding incremental network capacity is only needed to support actual growth in user traffic, not just to enable migration from one service to the next. A final benefit in this scenario is that, with a unified packet-access network, adding network capacity is simply a point-and-click provisioning process.

*Quality, Latency, and Clocking*

Users of mobile services expect to have connectivity with their network; they expect their calls to be completed; and they expect high-quality audio for their voice calls. So, quality and reliability are prerequisites to any discussion of new technologies in the RAN. Based on real deployments in the RAN, Axerra’s solution provides an extensive set of fault indications, traffic statistics, and performance monitoring tools. These capabilities furnish network operators with continuous, real-time visibility to control and diagnose the operation of their networks.

Latency is often an issue of paramount importance in wireless networks, not only due to its impact on voice quality, but because some signaling and control protocols cannot tolerate additional delay. End-to-end delay must be minimized while accommodating delay variations in the packet network. Axerra’s Pseudo-Wire solution allows network operators to control a number of parameters that affect end-to-end delay, including frame/packet size, jitter buffer size, queuing...
priority, and frame/packet priority marking via 802.1q/p and DiffServ. In addition, AXNs employ a number of unique enhancements to reduce latency and minimize bandwidth utilization for both circuit emulation and service emulation. Extensive testing by service providers confirms that Axerra’s solution delivers the lowest latency and meets the rigorous requirements of wireless signaling and control protocols.

Another requirement for reliable backhaul of mobile services is synchronization or clocking. Cell sites must utilize a clock source that is synchronized with the overall network clock. While some CDMA deployments use GPS receivers at the cell site to furnish this clock, most implementations rely on clocking to be distributed by the RAN together with the voice and data traffic. This clock must not only be very accurate, but must meet strenuous jitter and wander requirements. The delay variations inherent to packet networks induce jitter – which must be filtered out of clocks derived from Pseudo-Wire services. AXN access devices are equipped with Axerra’s adaptive clock recovery mechanism. ACR supplies a clean, accurate clock at the cell site, derived from a Pseudo-Wire bit stream transported over the packet network.

Even more stringent specifications are required in GSM/UMTS applications. AXN access devices are also available with a High-Precision Clock Recovery (HPCR®) mechanism for higher accuracy and greater temperature stability. ITU-T G.823\(^1\) and G.824\(^2\) as well as G.8261\(^3\) deployment case 2 clock recovery requirements and test cases. The HPCR® enables frequency accuracy of ±15 parts-per-billion (ppb) Fractional Frequency Offset (FFoFF) from the Primary Reference Source (PRS) clock. Axerra’s solution also offers a dedicated synchronization service using a separate ‘sync’ Pseudo-Wire connection. This has the advantage of allowing the clock recovery topology to be defined independently of the traffic flows. This leads to lower bandwidth utilization for clocking information, and a more flexible architectural structure with clock recovery independent of physical interfaces.

Axerra’s HPCR has been tested by mobile operators and confirmed to meet GSM/UMTS requirements, with measured accuracy within 15 parts per billion.

**Full-Service Solution**

In addition to maintaining the quality and reliability of mobile services, any new technology must retain the native features and advanced services from which operators derive value. Axerra’s circuit emulation and service emulation solution preserves complete transparency for signaling and control-plane protocols, even proprietary extensions to mobile protocols employed by some vendors. AXN access devices and gateways are fully interoperable with the equipment already installed in the BTS, the NodeB, the BSC/RNC, and/or the MSC. Operators can easily add AXNs to their existing architectures without changing the configurations of equipment already installed, while maintaining compatibility with all mobile voice and data applications.

Perhaps even more important, Axerra’s Pseudo-Wire solution is certified and supported by most of the top-tier mobile incumbent vendors. Mobile operators can be assured of the integrity and interoperability of this full-service solution, plus they can rely on their existing suppliers for sales, service, and support. In most cases, AXNs can be procured and supported through the entire life-cycle using existing processes and established relationships.

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\(^1\) The control of jitter and wander within digital networks that are based on the 2048 kbit/s hierarchy.

\(^2\) The control of jitter and wander within digital networks that are based on the 1544 kbit/s hierarchy.

\(^3\) Timing and synchronization aspects in Packet networks.
Conclusion

The exponential growth of the mobile market is fueled by the numbers of subscribers that keeps growing and the growing bandwidth per subscriber. The growing bandwidth per subscriber is due to bandwidth hungry services that are available through smartphones and makes the mobile providers upgrade the technology (to 3G, LTE and beyond) and install base-stations in higher densities. Mobile providers need to expand their coverage and increase their capacity to handle the demand for services. In today’s difficult economic times, mobile providers are concerned not only about meeting the growing demand for services, but also about the return on investment of their capital expenditures and the need to reduce operational costs, particularly in the RAN, as they expand and upgrade their networks from existing 2G/2.5G technology to 3G having in mind the need to support LTE and beyond.

By enabling the backhaul of all generations of voice and data traffic over a single packet-based RAN, Axerra’s Pseudo-Wire solution offers mobile operators a full-service alternative to TDM access and a means to substantially reduce backhaul expenses and enhance profitability. Axerra is the only vendor that can deliver today both small, low-cost access solutions and redundant, high-density, carrier-class solutions, optimally sized for mobile cell sites as well as for mobile central office and headend applications. Axerra’s AXN Pseudo-Wire Gateways and Access Devices provide the widest range of Pseudo-Wire services over flexible and cost-effective packet access networks such as Carrier Ethernet, xDSL, EPON/GPON, cable HFC, and broadband wireless (WiMAX).

Axerra Networks furnishes the industry's most complete range of service aggregation and Interworking solutions. Axerra's multiservice over packet (MSoP) technology enables incumbent carriers, mobile/wireless operators, and cable/MSOs to extend both profitable legacy and emerging services over their Carrier Ethernet networks, such as: IP/MPLS, Ethernet, DOCSIS HFC networks, etc.

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