

UNSTRUNG **insider**

TARGETED ANALYSIS OF THE WIRELESS INDUSTRY

Ethernet-Capable Mobile Base Stations

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Report Highlights

Ethernet and IP RAN capability will be critical to most 2008 base-station purchasing decisions and a key enabler of packet-switch transmission networks

The first Ethernet-capable base stations, with support for both 2G and 3G "IP RAN" protocols, appeared on the market in 2007; more products from all major vendors are scheduled for general availability in 2008

With traffic growth fastest in the existing 3G footprint (i.e., urban centers), we anticipate a strong retrofit market for Ethernet transport modules, as operators upgrade existing cell sites

Huawei leads the market in terms of commercially available IP RAN capability and has full Ethernet support across its base-station portfolio; Alcatel-Lucent, Ericsson, Nokia Siemens, and Nortel will all respond strongly in 2008

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I. Introduction: Modernizing Mobile Infrastructure

There's a glaring irony in the mobile infrastructure market: Innovation in the core base station radio technology is occurring rapidly, 3G access networks have ushered in the era of mobile broadband, traffic growth is exploding, and the promise of higher-capacity next-generation WiMax and Long Term Evolution (LTE) systems is around the corner; yet despite being home to some of the most advanced networking technology ever developed and deployed, mobile networks remain ill-prepared for data and hamstrung by their reliance on voice-oriented TDM transport over E1/T1 leased lines. While the rest of the world moves to packet-based network architectures, vast numbers of cell sites in the most developed economic regions are still connected by technology developed by Bell Labs in the 1950s and first deployed by AT&T Long Lines in 1961.

For mobile operators with ambitions to compete in the Internet services market, this dependence on leased lines and TDM transport is financially unsustainable. The move to packet, as elsewhere in telecom, is inevitable, and there's now huge interest in carrier Ethernet for mobile backhaul.

Taking maximum advantage of IP/Ethernet economics requires not just an upgrade in the transport domain, but also the emergence of compatible cell-site equipment. Cell sites can be Ethernet-enabled using specialized gateway equipment – a fairly common strategy today. However, if operators are to truly reduce the cost of delivering mobile data to their subscribers, base stations themselves will ultimately need to present an Ethernet port to the network.

The first Ethernet-capable base stations with support for native "IP RAN" protocols appeared on the market in 2007, with a small number of forward-looking Asian operators deploying the technology in live, commercial networks during the second half of the year. These are still isolated early adopters, however, and not yet reflective of the industry mainstream.

This report provides a systematic overview of equipment suppliers' strategies for adding Ethernet capability to 2G and 3G base stations. Broadly speaking, the addition of Ethernet ports to mobile base stations enables three new transmission models:

- Hybrid backhaul via data offload: In this scenario, best-effort data traffic is split out from the delay-sensitive signaling and data traffic and sent over a lower-cost transmission link.
- Ethernet backhaul using pseudowire encapsulation for ATM and TDM: This is used where the base-station transport module has an Ethernet interface (and pseudowire capability) but doesn't support IP RAN protocols.
- Ethernet backhaul of native IP RAN traffic: This scenario involves transport of the Abis and lub over IP and is the long-term target architecture for 2G and 3G operators.

Companies covered in this report include: Alcatel-Lucent (NYSE: ALU); Ericsson AB (Nasdaq: ERIC); Fujitsu Ltd. (Tokyo: 6702; OTC: FJTSY); Huawei Technologies Co. Ltd.; Motorola Inc. (NYSE: MOT); NEC Corp. (Nasdaq: NIPNY); Nokia Siemens Networks B.V., a joint venture of Nokia Corp. (NYSE: NOK) and Siemens AG (NYSE: SI; Frankfurt: SIE); Nortel Networks Corp. (NYSE: NT); and ZTE Corp. (Shenzhen: 000063; Hong Kong: 0763).

II. Drivers for Ethernet Backhaul

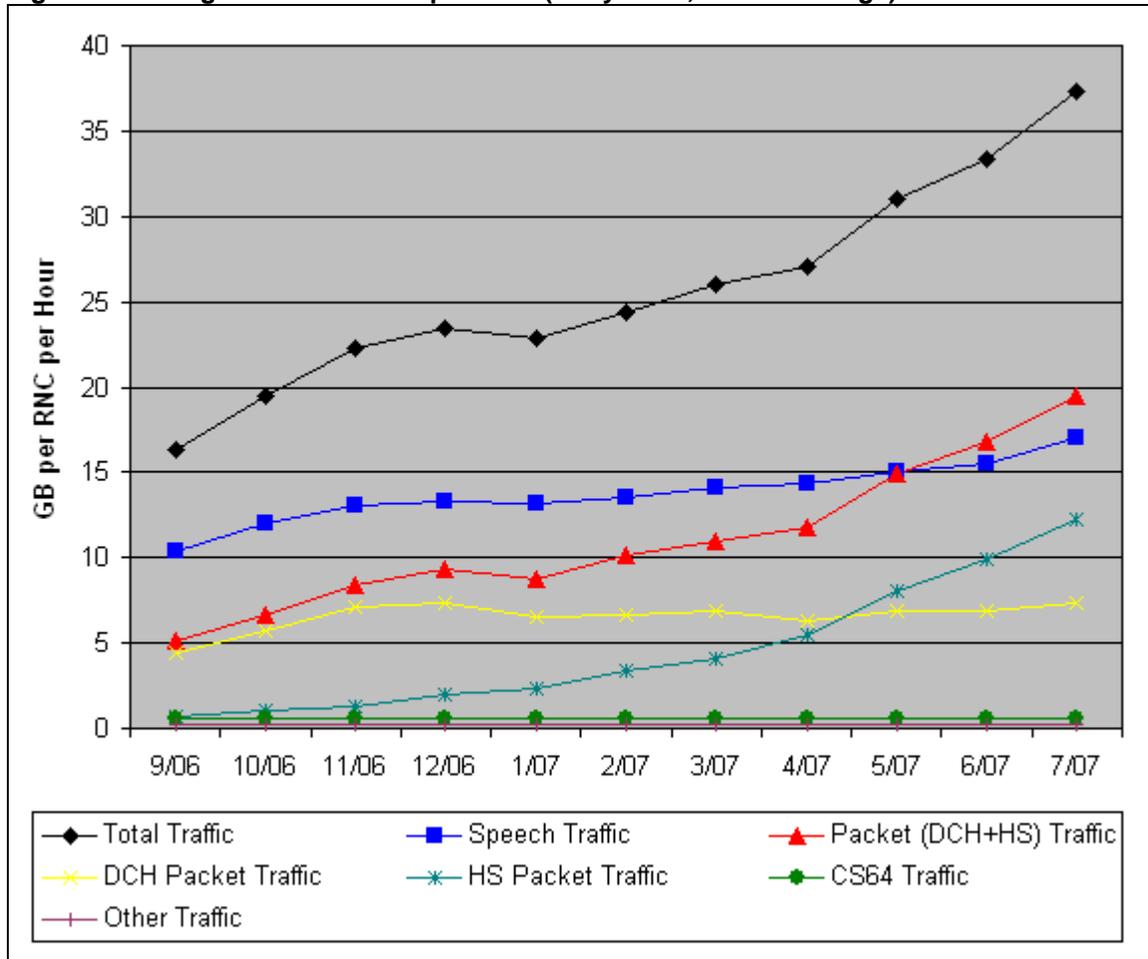
A. Data Traffic Growth

After years of promise, and fully four years after the first 3G networks were launched, data traffic on mobile networks is now surging. The increase in traffic is being driven primarily by laptop users equipped with USB modems and contracted to flat-rate data plans. Notably, data-plan prices have come down considerably in 2007 in some markets, with operators such as 3 UK now offering 1 GB of data for as little as £10 (\$20) per month.

With even lower prices for flat-rate data using handsets (normally with fair-use conditions) and the emergence of applications such as Internet radio and mobile video that generate far more traffic than simple Wireless Application Protocol (WAP) browsing and messaging applications, mobile data has become a mass-market phenomenon. According to operator and vendor sources, larger 3G operators in the Big Five European countries are now seeing data-traffic volumes on the order of a terabyte per day, up from just 250 GB in the autumn of 2006. This growth looks set to continue through 2008.

In September 2007, Ericsson released figures on the average busy-hour throughput across its radio network controllers (RNCs). This is shown in **Figure 1**, expressed as gigabits of traffic per RNC per hour. A typical RNC would support between 100 and 300 base stations.

Figure 1: Average Traffic Volume per RNC (Busy Hour, World Average)



Source: Ericsson Strategy & Technology Summit (London, September 2007)

Looking at a six-month view, the chart shows that global average busy-hour throughput per RNC increased between February 2007 and July 2007 as follows:

- All traffic up ~50 percent to 37.5 GB per RNC
- Packet traffic up ~100 percent to 20 GB per RNC
- HSPA traffic up ~240 percent to 12 GB per RNC

Clearly, the upgrade to High Speed Packet Access (HSPA) in late 2006 and the first half of 2007 is driving the traffic increase. And it should be noted that penetration of HSPA-capable modems and devices is still relatively low; as more users come online, traffic volumes will increase and growth rates may even accelerate. Also note that **Figure 1** shows the world average; many operators are experiencing much faster growth rates. For example, in an "aggressive operator" scenario, Ericsson indicated that busy-hour HSPA traffic was more than 50 GB per RNC in July 2007 – a more than fivefold increase in just six months.

B. Backhaul Costs

Given that flat-rate plans are partly responsible for the increase in traffic on 3G networks, the challenge for operators is how to serve this at an appropriate cost point, as revenue and traffic are now decoupled. The key variable is the cost of backhaul, since most other costs of service delivery are already part of the sunken investment in cell sites, base stations, core network equipment, and so on. This will remain the case until new, lower-cost backhaul is in place and/or operators need to deploy additional radio capacity to their cell sites.

Assessing the cost of backhaul is difficult because operators have such different profiles, with some focused on self-build (usually via microwave), while others use leased services from local wireline carriers. Where leased services are used, it's typically a T1/E1 leased-line service over copper pairs, with prices varying dramatically according to the country and location within a particular market. As a very rough guide, prices as low as \$200 per T1 are seen in high-density urban markets in the U.S., while the price for an E1 in Europe would be between 300 and 500 (\$440 and \$735) per month in urban areas. Suburban and rural prices are often far higher.

These prices are sustainable for mobile voice services, but unsustainable when applied to flat-rate data services. The table below shows an estimate of how backhaul requirements could evolve. For a high-demand 3G site in a city center, it assumes that three sectors and three carriers are deployed by 2012, and required to support peak throughput of 4 Mbit/s per carrier (i.e., 4 Mbit/s x 3 sectors x 3 carriers = 36 Mbit/s).

Figure 2: Cell-Site Transmission Requirements

Scenario	Average Site	High-Demand Site
2007 (Mbit/s)	6 Mbit/s	12 Mbit/s
2007 (E1s)	3 x E1	6 x E1
2012 (Mbit/s)	16 Mbit/s	36 Mbit/s
2012 (E1s)	8 x E1	18 x E1

Source: *Unstrung Insider*

While it's technically possible to support these peak rates on T1/E1 leased lines, it's impractical and likely not cost-effective. The impact is stronger where large numbers of sites need to be backhauled at higher speeds, since cost multiplies much faster than revenue. The ideal solution is to move to a new low-cost transport model. Carrier Ethernet is the clear technology of choice due to the lower cost of switching equipment and its cost curves from an interface perspective.

III. Ethernet-Enabled Cell Sites

With rapid traffic growth, mobile operators need IP/Ethernet connectivity to the cell site. Connectivity can be delivered over a variety of physical media, including optical fiber, copper pairs, and microwave radio. If an Ethernet interface is required at the cell site, there are two ways to achieve this: by adding Ethernet capability to the base station, or through the use of a gateway/demarcation device linked to the transmission service or infrastructure.

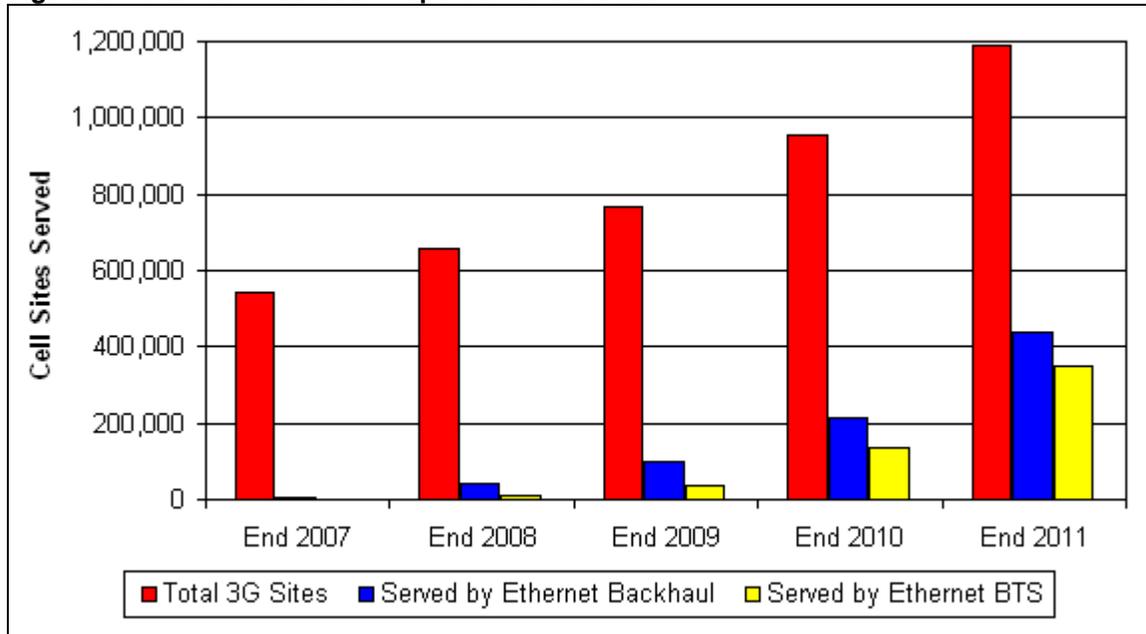
Both options are valid. In the standardization process, the interfaces between base stations and RNCs are kept distinct from the underlying transport, in order to facilitate the introduction of new transmission technologies in the future. Separation of layers in the protocol stack also allows multiple protocols to share the same transmission network – for example, Abis (GSM) and Iub (UMTS) may be transported over the same transmission links.

The bearer for base station-to-RNC traffic is typically ATM over various transmission types (normally E1/T1). With time, however, the market is expected to move to IP/User Datagram Protocol (UDP) over a variety of transmission types, and ultimately over carrier Ethernet.

A. Forecast of Cell-Site Ethernet Connectivity

Figure 3, excerpted from *Heavy Reading's Ethernet Backhaul Quarterly Market Tracker* (November 2007), shows a forecast for Ethernet-enabled cell sites.

Figure 3: Ethernet BTSs as a Proportion of 3G Sites



Source: Heavy Reading

The chart forecasts the growth in the installed base of Ethernet base transceiver stations (BTSs) carrying live traffic over an Ethernet backhaul in the network. The number of sites and base stations that are "Ethernet-ready" but not yet served by a live Ethernet backhaul will be higher.

The forecast foresees 10,514 3G Ethernet base stations carrying commercial traffic worldwide by the end of 2008, with that figure rising to 348,535 by the end of 2011. By 2011, 23 percent of Europe's 3G sites will be supported by native Ethernet base stations. These forecasts imply that Ethernet backhaul will see rapid deployment and that Ethernet interfaces will become standard configuration on base stations.

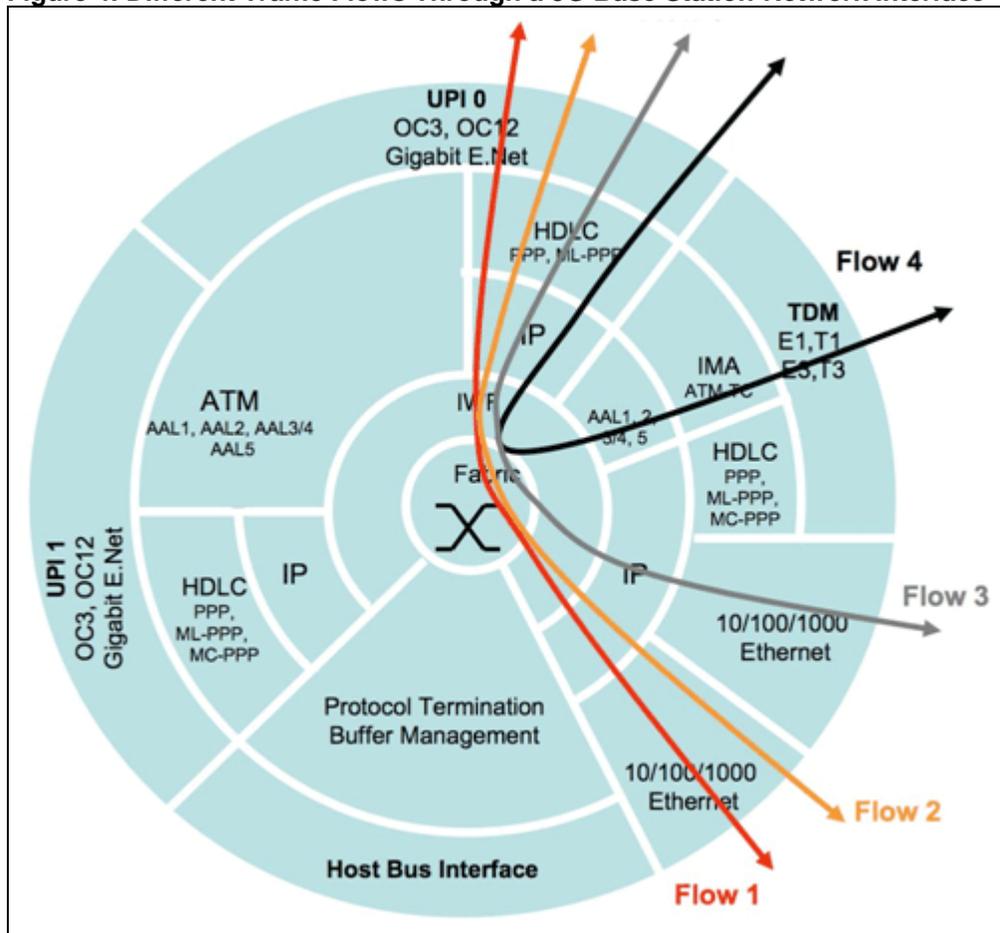
B. Ethernet-Enabled Base Stations

Base stations traditionally comprise three modules: an RF head, a baseband processing unit, and a transport module. The transport module, which provides the interface to the transmission network, is the least glamorous of the three.

Base-station transport modules typically present E1 ports to the network. This is ideal for 2G networks, which specify TDM transport and have low capacity requirements. In 3G networks, ATM was standardized at the link layer and uses Inverse Multiple Access (IMA) techniques to multiplex ATM traffic across several E1 connections. More recently, IP was specified for RAN transport (in UMTS, this was part of the Release 5 specifications). IP RAN may use techniques such as Multi-Link Point-To-Point Protocol (PPP) to multiplex traffic across E1/T1 lines.

Both ATM and IP typically depend on T1/E1 transport to the cell site over copper pair, fiber, or microwave. Ethernet can also be used to transport TDM, ATM, and IP RAN traffic, and may be desirable where traffic volumes are high. Where TDM and ATM bearers are used, however, pseudowire technology is required to provide circuit emulation. Note also that Ethernet services are often delivered over next-gen Sonet/SDH networks, which are, ironically, TDM-based.

Figure 4: Different Traffic Flows Through a 3G Base Station-Network Interface



Source: Wintegra

This all adds up to a situation in which a significant number of variations in the protocols must be supported over different Layer 1 and Layer 2 combinations. This potential complexity is driving a requirement for greater flexibility in the base station-network interface. Equipment vendors have responded by adopting network processors that can be configured in software to handle these

different requirements. These processors must terminate the network interface protocols and then interface with the rest of the base station, passing user- and control-plane signals as required. **Figure 4** shows this with different flows through the protocol maze.

Focusing on Ethernet specifically, there are two ways to add Ethernet interfaces to base stations: upgrade the network card in legacy base stations, or ship new base stations with native Ethernet.

Upgrading the transport card in existing base stations is usually technically possible, since base-station designs are typically modular. With traffic growing fastest in the existing 3G footprint (urban centers, etc.), a strong retrofit market for Ethernet transport modules is anticipated as operators upgrade existing cell sites. Perhaps the most appropriate time to upgrade the transport module would be when new radio carriers are deployed to increase cell-site capacity. This would especially be the case with the move to an additional HSPA carrier, which would double backhaul requirements at a stroke (assuming it was fully used).

For new base stations, Fast Ethernet or Gigabit Ethernet ports are gradually becoming part of the standard configuration. This is especially the case with data-oriented 3G Evolution Data Only (EV-DO) and HSPA products. Ethernet, however, will often be supplementary to T1/E1 ports, with a typical configuration being two Fast Ethernet and four or eight E1 ports. This requirement to support both Ethernet and T1/E1 is controversial in the sense that it adds to the product's cost, but it does allow greater deployment flexibility. This is useful, for example, when the operator is uncertain about the transport options likely to be available at the site in future.

Another reason a mix of Ethernet and T1/E1 ports is useful is that it would allow an operator to support a hybrid backhaul architecture, with best-effort data traffic sent over the Ethernet interface and voice, synchronization, and signaling sent over T1/E1. Ultimately, however, the real value of Ethernet will be seen when all traffic is sent over this interface. WiMax and future LTE equipment, for example, will all support Ethernet from the outset.

C. Cell-Site Gateways/Demarcation Devices

Another way to Ethernet-enable a site is through the use of specialist cell-site gateway equipment. This is typically a 1U or 2U device that sits at the cell site and acts an intermediary between the transmission network and base stations.

This cell-site gateway can be used to aggregate and packetize traffic from multiple base stations at the site (as well as neighboring sites) without any need to upgrade installed equipment. Features of this equipment include multiple types of traffic-management and switching functions such as grooming, optimization, multiplexing, quality-of-service marking, data offload, and pseudowire encapsulation. Typically, it would offer a mixture of Fast Ethernet, Gigabit Ethernet, T1/E1, and potentially STM1/OC3 interfaces.

There's some debate over which party should own and manage this device. Some argue that this falls within the mobile operator's domain, in part because this gateway equipment means the site is ready for whatever transmission services are available at that location. The downside is that such devices are hard for mobile operators to manage, which leads to the opposing argument that the transport provider should offer and maintain such equipment, as part of its overall network-management services. In this way, the gateway is equivalent a demarcation device that carriers would deploy at enterprise sites.

Where microwave is used, the indoor unit (in the classic split-mount architecture) is sometimes capable of advanced traffic processing and can act as a gateway for multiple generations of base station. Viability depends on the age and capability of equipment installed at the site. For more on this topic, see the *Unstrung Insider* report **Mobile Backhaul & Cell Site Aggregation: State of the Art** (Vol. 6, No. 2, February 2007).

IV. Base-Station Vendor Roadmaps

A. Alcatel-Lucent (NYSE: ALU)

Alcatel-Lucent is one of the top three mobile-infrastructure suppliers worldwide, and the only large vendor involved in all three major wireless standards initiatives: 3GPP, 3GPP2, and IEEE 802.16/WiMax. The product group interviewed for this report was Alcatel-Lucent's UMTS radio-access division. The vendor has now streamlined its UMTS portfolio on a new, converged product set that has its origins largely in the ex-Nortel equipment line, complemented by some elements from the ex-Alcatel and ex-Lucent UMTS products.

Alcatel-Lucent has recently introduced a new version of its Node B network-interface card, known as the Core Control Module (CCM), under the name xCCM. This module controls the interaction between the transmission network and the baseband processing functions of the base station. The new module has the same form-factor as its predecessor, known as iCCM, and will be the reference hardware used across all types of macro Node B. The standard configuration is 8 x E1/T1 ports and 2 x Fast Ethernet, although the design is such that a newer version could be equipped with Gigabit Ethernet if required. The module is software-configurable, and thus flexible enough to support a wide range of transport options.

The module has already shipped to first customers for evaluation and will be generally available from early in the first quarter of 2008. It can be retrofitted to deployed base stations, but this is not expected to be a large market. Initially the module will support a hybrid backhaul approach, with best-effort data traffic offloaded to Ethernet and more sensitive traffic retained on the ATM over E1 interfaces. Through a software upgrade planned for mid 2008 and expected to be generally available during the second half of the year, xCCM will add full support for lub over IP.

Because the specific protocols involved in each type of cellular standard are different, there's variation across the vendor's product lines in terms of the how the transport card is implemented. For example, the CDMA base-station group has a different transport module than the Wideband CDMA (WCDMA) group or the GSM group.

Of the Alcatel-Lucent CDMA products, the Modular Cell 4.0B (a high-density macro base station) has supported Ethernet backhaul as a generally available feature since November 2007 for both 1X and EV-DO. Ethernet capability will be rolled out to the more compact (up to four carriers in three sectors) Modular Cell base station in summer 2008. For newer, all-IP wireless technologies such as LTE and WiMax that don't have a TDM or ATM legacy, base stations will support Ethernet natively from the start.

Despite the variation of radio interface technologies, Alcatel-Lucent is working across its portfolio to align base-station connectivity with its recently introduced Mobile Evolution Transport Architecture (META) – a set of transmission products intended to support operators seeking a staged evolution from TDM and ATM to an all-IP backhaul infrastructure.

B. Ericsson AB (Nasdaq: ERIC)

Ericsson is the largest supplier of mobile base stations worldwide. With its focus on 3GPP-track technologies (GSM, UMTS, and, in the future, LTE), it has a simpler roadmap than many of its competitors and can focus its R&D scale advantage on fewer products. It also does not have the M&A challenge of integrating products with different heritages. Representatives from both the GSM and 3G products groups were interviewed for this report.

Ericsson sees strong demand for native IP/Ethernet connectivity in both 2G and 3G base stations in all global regions. Its entire portfolio is being aligned to this view. At the launch of its Radio Base Station (RBS) 3000-series platform for 3G networks in February 2006, Ericsson cited the ability to upgrade to IP/Ethernet transport as an important feature of the product architecture – even though at the time, 3G transmission was all about ATM over E1. Today, the transport card

in RBS 3000 products is typically a 4 x E1 module, with an expansion module that increases port count to 8 x E1 also available. There is an option for an STM1 interface, although this is not widely used today.

From an IP/Ethernet perspective, a new plug-in transport module, called the ET-MSX, offers 6 x Fast Ethernet ports and native lub over IP connectivity. It can also be installed alongside the existing four-port E1/T1 module to support hybrid backhaul. This new IP/Ethernet module is currently in multiple operator trials and will be generally available from January 2008. Ericsson is already actively marketing the capability, and interest is said to be strong from all global regions and especially from operators where HSPA traffic is growing rapidly.

Whereas most new base stations are currently deployed as tail sites and traffic aggregation is done in the network, the new transport module will also be able to aggregate traffic from other base stations at the site, such that only one access port is presented to the network.

The firm cites several advantages to IP/Ethernet interfaces being integrated into the base station over third-party cell-site gateway products. These include lower capital costs and simplified operation due to integration with the Ericsson network management systems. There's also an opportunity for traffic shaping and traffic optimization to be carried out at the cell site rather than in the network, potentially increasing the transmission network's efficiency.

In GSM, Ericsson notes that the standards are now 20 years old and that, despite the technology working extremely well, there are opportunities to enhance network economics through the introduction of IP backhaul and Abis optimization. It estimates that a combination of IP and Abis optimization can generate bandwidth savings of between 30 percent and 60 percent.

Ericsson says it has four customers currently running Abis over IP across Ethernet interfaces built into its micro and pico base stations. From January 2008, it will offer an Ethernet-capable "in-built site aggregation unit" for its GSM macro products. The module will support Abis over IP and, as the name implies, will also allow operators to aggregate cell-site traffic. Importantly, this includes traffic from 3G base stations.

Both the new 3G and GSM transport modules will be backward-compatible with the majority of installed equipment, and Ericsson expects a strong retrofit market with a return-on-investment case built around transmission savings.

While RAN nodes and transmission are distinct business and product groups, Ericsson points to common ground between the two and how it works to align the respective roadmaps. For example, general availability of its Ethernet-capable base stations is aligned with the availability of Ethernet microwave products. Another area it highlights is its professional-services capability in the IP RAN domain and how it can support operators in determining optimal performance configurations for base stations, radio controllers, and transmission equipment.

C. Fujitsu Ltd. (OTC: FJTSY)

Fujitsu is best known in the mobile infrastructure market for its position as a leading supplier of WCDMA equipment to NTT DoCoMo in Japan (the world's largest 3G operator). Through a joint development initiative with DoCoMo, Fujitsu is also pioneering the transition to LTE, in which it was the first named vendor partner for the carrier.

Fujitsu's 3G products have supported IP RAN over Ethernet interfaces since 2006. The typical transport module configuration is 2 x Fast Ethernet ports and 8 x E1/T1 ports. This early move to Ethernet is partly explained by the nature of Japanese base-station deployments, which often use fiber-fed remote radio heads and centralized, high-capacity baseband server units. There is also often fiber available at the baseband server location. We were unable to confirm whether all traffic is sent over IP/Ethernet, or if that is used in a hybrid model for data traffic – and therefore suspect the latter.

As the vendor enters the mobile WiMax and LTE markets, it is seeking to expand its business outside Japan. Its co-development on LTE with DoCoMo, for example, should give it early momentum and technical credibility. But, more so than in the past, the operator also wants the economies of scale that come with global business and appears to be encouraging Japanese vendors to internationalize.

Fujitsu's coming LTE equipment will use Ethernet from the outset. The LTE base stations are based on Gigabit Ethernet connectivity, which Fujitsu believes is necessary because a three-sector LTE base station using 4x4 multiple input, multiple output antennas is already capable of peak throughput of 900 Mbit/s. WiMax is also native Ethernet. Where required, the firm is pairing base stations with packet microwave backhaul products from DragonWave and Ceragon to offer an integrated radio and transmission solution.

Fujitsu also has a strong transport portfolio, especially in North America, where it is a leading supplier of next-gen Sonet systems. A substantial portion of its next-gen Sonet demarcation devices are sold to wireline operators but installed at cell-site locations.

D. Huawei Technologies Co. Ltd.

Huawei is active in all leading mobile technologies, with a focus on the 3GPP (GSM/UMTS/LTE) track. We interviewed representatives of the wireless product groups for this report. Huawei says that all its current-generation base stations support Ethernet interfaces and IP RAN transport, including the 38-series (UMTS), 37-series (WiMax), 36-series (CDMA), and 30-series (GSM).

Its CDMA base-station platform, launched in April 2007, offers both T1/E1 and Fast Ethernet ports and supports Abis/IP over either medium. A hybrid mode is also offered so EV-DO traffic can be sent over Ethernet and 1X over T1/E1. The vendor has a number of reference customers for this product, most recently demonstrated by the announcement of a deal in the Ukraine.

In UMTS, Huawei has the most aggressive lub/IP deployment schedule in the industry. With its "RAN 6" release in April 2007, it introduced simultaneous support for ATM and IP, making it the first to offer lub/IP as a generally available feature on macro base stations.

Reference UMTS customers include EMobile in Japan, which is deploying an all-IP 3G RAN using Huawei equipment and which began operation in the summer of 2007. Another reference is Etisalat in the United Arab Emirates. It is also understood that another Asian operator is running all-IP HSPA service using Huawei equipment. Specifically, this operator is using Ethernet-capable base stations backhauled over a multi-service carrier Ethernet network also provided by Huawei.

In October 2007, Huawei said it had become the first vendor to offer an all-IP GSM base-station subsystem through China Mobile. It noted, however, that this was an Abis/IP-over-E1 installation, rather than over pure packet transport. The vendor has also introduced a "fractional PPP" feature that provides a way for UMTS base stations to share transmission resources with 2G base stations to offer a "one-pipe" cell-site backhaul scenario.

E. Motorola Inc. (NYSE: MOT)

Motorola was unable to provide a spokesperson in time for this report. As noted in previous *Unstrung Insider* reports published this year, the vendor appears to be putting most of its forward-looking development behind WiMax and LTE, and de-emphasizing 3G technology other than for femtocell applications – and even here, it's partnering on the base-station side. 2G GSM and CDMA 1X/EV-DO continue to be supported, but it is unclear whether Motorola views this as strategic or a mature business to be run for cash.

In March 2007, the vendor announced a new "universal base station" platform, which it says will support CDMA and LTE applications. This would presumably offer Ethernet ports to the network. In WiMax, the firm recently announced it had 44 trial engagements by the end of 2007.

F. NEC Corp. (Nasdaq: NIPNY)

NEC was unable to provide a spokesperson for interview in time this report. However, the firm is known to be a longtime supporter of the IP RAN concept and was one of the first to introduce the pooled-RNC concept for 3G. We understand that NEC's European products currently support E1 interfaces (and STM1, if required) and that, while it plans to offer an Ethernet option in the future, no detailed timeline was in place for this as of the 3GSM trade show in the winter of 2007.

NEC's 3G joint venture with Siemens has clearly been affected by the merger between Siemens Communications and Nokia Networks, but the firm appears comfortable with its newfound independence. Its European 3G focus now appears to be on femtocells and professional services. NEC's other big push is into LTE and WiMax: In December 2007, it announced it had been selected as an LTE vendor partner by DoCoMo. These are IP/Ethernet systems by design.

G. Nokia Siemens Networks B.V.

Nokia Siemens, a joint venture of Nokia Corp. (NYSE: NOK) and Siemens AG (NYSE: SI; Frankfurt: SIE), is the second-largest supplier of cellular infrastructure worldwide, with a focus on 3GPP technologies (GSM, UMTS, and LTE). It also has an emerging interest in mobile WiMax.

Since the merger, the firm has worked to integrate the Nokia and Siemens base-station portfolios through a common RNC, which is scheduled for general availability in early 2008. This RNC will offer Gigabit Ethernet ports and support lub and lu over IP. The respective base-station portfolios will be maintained as separate products lines, however, due to the volume of installed equipment and the size of the respective customer bases.

The key base-station platform will be the FlexiBTS developed by Nokia Networks. The transport module in the 3G version offers 4 x E1, 2 x Fast Ethernet, and 1 x Gigabit Ethernet ports to the networks and has been shipping for a year. The vast majority of deployments use E1 interfaces, but the hardware is prepared for packet backhaul. For example, it already supports offload and has integrated pseudowire capability.

The module does not yet support native lub/IP, but Nokia Siemens says the software is being used in demonstrations and trials. It will be generally available as a software upgrade in the fourth quarter of 2008. This schedule aligns with the availability of an IP plug-in module for the already-deployed ex-Nokia RNCs. Nokia Siemens believes western 3G operators are looking very favorably on native lub/IP RANs over the medium term, even though they're not yet ready to deploy them widely. The same transport module used in the Flexi can be retrofitted to the older ex-Nokia UltraSite 3G products, and the vendor says it is now seeing much stronger interest in this retrofit market.

Nokia Siemens has an alternative approach for the ex-Siemens 3G products. These products will be made Ethernet-capable through an external module based on a demarcation device used in enterprise access applications but running dedicated mobile software. The device will support offload and pseudowire encapsulation. The module is currently in field trials and can be made generally available in short order if market demand materializes. Although it's external, this module is integrated mechanically with the base station (slots into the same cabinet) and is integrated from the point of view of the network management system. It does not, however, connect to the base-station backplane, instead using E1 cables.

Across its portfolio, Nokia Siemens says it has more than 20 3G operators interested in and evaluating the Ethernet capabilities of its base stations. It also says that two Asian operators are running live commercial traffic over Ethernet: One is running entirely over Ethernet microwave using ATM pseudowires, while the other is using Ethernet ports to offload data traffic in a hybrid backhaul architecture. In September 2007, Nokia Siemens announced a deal with Chunghwa Telecom in Taiwan that will use the Flexi base station's Ethernet port as part of a hybrid backhaul architecture. The firm notes, however, that this deployment is not yet carrying commercial traffic.

In GSM, Nokia Siemens's Flexi GSM/EDGE products already support Abis/IP over E1 and will be offered across an Ethernet interface from the first quarter of 2008. However, the base station controller will not support Abis/IP until the second quarter of 2009; in the meantime, operators will need to use an external gateway device. The same hardware and software base used in the Flexi GSM/EDGE transport module is also being developed for the ex-Siemens BTS 2040 product line, for which it will be generally available from the third quarter of 2008.

Nokia Siemens sees the greatest near-term demand for Abis/IP coming from China, where there is deep fiber penetration and strong operator desire to move to packet backhaul. There's also strong demand in India, due to capacity constraints on microwave transmission facilities. The firm expects substantial deployments in both regions in 2008. It's also seeing significant interest in North America and says Western European operators are reevaluating Abis optimization.

In terms of combining 2G and 3G transmission, the vendor says it's involved in a great deal of trial and evaluation activity for a "one-pipe" solution, but that it's too early say how big this will be. It notes that, with the majority of sites connected with microwave, the point is moot insofar as aggregation can equally be performed in the network.

H. Nortel Networks Corp. (NYSE: NT)

Nortel is a provider of CDMA and GSM cellular infrastructure, primarily in Europe and North America. It has aggressive plans to enter the mobile WiMax and, particularly, the 3GPP LTE markets. The CDMA/LTE product group (which represents the heart of Nortel's forward-looking business) was interviewed for this report.

The vendor's key CDMA base-station platform is the Metrocell high-density macro product line, which can support up to 12 carriers per cabinet. This supports both 1X and EV-DO. From a 1X perspective, the Metrocell platform uses a transport module called the Enhanced Digital Control Group. Early versions of this supported 8 x T1. The newer version, already generally available, supports 16 x T1 and 2 x Fast Ethernet ports.

For the most part, Nortel says that customers are generally happy to continue T1 transport for 1X equipment and reluctant to make substantial changes to a proven and trusted backhaul model. In the longer term, however, it does see operators wanting to send 1X traffic over IP and will offer a software upgrade in the second half of 2008 to the Enhanced Digital Control Group module that leverages the two Ethernet ports for this purpose.

Particularly where there is already significant EV-DO traffic at the site, Nortel sees the push to enhanced services over Rev A as starting to affect how transmission networks are designed and deployed. This is seen as accelerating demand for IP backhaul over carrier-grade Ethernet.

Nortel says the 1X base station controllers already support four Gigabit Ethernet interfaces (to enable pooled functionality), and that it's a relatively simple software upgrade to enable 1X over IP from the base station. Similarly, the EV-DO RNCs also support Gigabit Ethernet.

The upgrade to EV-DO for CDMA operators is interesting in that it was IP-oriented technology from the outset. As such, CDMA carriers have operated IP RANs for several years. The Nortel EV-DO implementation consists of an EV-DO module upgrade to existing 1X base stations such as the Metrocell products. The module is a self-contained baseband processing unit with integrated network-interface capabilities consisting of 4 x T1 and 2 x Fast Ethernet ports.

The EV-DO module can, in theory, connect directly to an IP/Ethernet backhaul. More often, however, the Fast Ethernet ports are used to port the EV-DO module to the Enhanced Digital Control Group transport card in the host base station. IP traffic is then multiplexed over T1. The EV-DO module does not connect to the Enhanced Digital Control Group transport card through the base-station backplane. This setup is appealing because it enables flexibility (for example, EV-DO can be deployed in standalone mode) and is practical in that most North American sites

are served by T1 only. Ultimately the firm anticipates a "single-pipe" backhaul, where both 1X and EV-DO are multiplexed over a single group of T1s or, perhaps more likely, where all traffic is sent over an Ethernet interface.

As the market moves to deploy LTE technology, Nortel is evaluating how it can be deployed at the cell site in such a way as to maximize reuse of installed equipment such as feeders, antennas, and power supply. Integrated transmission is part of this evaluation.

On the wireline side, Nortel is a leading supporter of connection-oriented carrier Ethernet and, while transport and RAN equipment are clearly separate business groups, the firm will inevitably look to align the respective roadmaps.

I. ZTE Corp. (Hong Kong: 763)

ZTE did not respond to requests to be interviewed for this report, but it is active in a wide range of standards, including CDMA, UMTS, GSM, WiMax, and Time Division-Synchronous CDMA, with CDMA to emerging markets accounting for the bulk of its revenues. The company markets heavily around the all-IP mobile network concept, and while this has primarily been focused on the core network and the upgrade to a softswitch architecture, ZTE is starting to push the Abis-over-IP story in the RAN in whitepapers and other marketing literature. It notes, however, that this is primarily Abis over T1/E1 transport, rather than over Ethernet.

In product literature, ZTE says it supports STM1 interfaces on macro CDMA base stations, a feature that is likely applicable in China, where a large proportion of cell sites are connected by fiber and there is deep penetration of next-gen SDH transport. It appears that none of the firm's publicly available marketing material makes explicit reference to Ethernet interfaces on its base stations – a curious finding, given that Chinese operators are among the most aggressive in adopting IP RAN over carrier Ethernet.

V. Conclusions

While Ethernet backhaul is not yet a mainstream technology and is on an adoption curve linked to the availability of faster connectivity to cell sites, mobile operators worldwide are planning for an increased role for carrier Ethernet backhaul in the medium and longer term. For this reason alone, Ethernet and IP RAN capability will be critical to the majority of mobile operator base-station purchasing decisions in 2008.

The first Ethernet-capable base stations with support for native IP RAN protocols appeared on the market in 2007, but they have been deployed in live, commercial networks only by a minority of forward-looking operators. With more products from all the major vendors scheduled for general availability in 2008, the market for packet backhaul is set to grow rapidly.

While primarily applicable to 3G and next-gen WiMax and LTE networks (IP by default), due to the spiraling volumes of data traffic being generated by flat-rate mobile Internet services, base-station Ethernet capability is also seen as increasingly important to 2G networks. Ethernet not only delivers efficiencies in its own right, but it also enables operators to achieve maximum efficiency by backhauling all 2G and 3G data traffic over the same packet-switched transmission network. For this reason, Ethernet capability for GSM and CDMA 1X base stations is also now critical to mobile operator purchasing decisions.

There remains some debate over the retrofit market for Ethernet transport modules. The large incumbent 3G vendors, such as Ericsson and Nokia Siemens, are the most enthusiastic voices in this area. They argue that the majority of traffic growth is occurring in areas that are served by the existing 3G network footprint, and therefore that these areas, which are likely relatively close to fiber, have the greatest need to upgrade to carrier Ethernet. It's hard to fault this logic, but the operator business case will depend heavily on vendors pricing their new IP-capable transport modules appropriately.

Figure 5 summarizes the current Ethernet capability of each vendor's mobile base stations. It also notes when key features will become generally available, if not currently supported.

Figure 5: Summary of Base-Station Ethernet Capability

Vendor	GSM	UMTS	CDMA
Alcatel-Lucent	Information not collected	New transport module generally available in 1Q08; lub/IP from mid 2008	Generally available since 4Q07; supports 1X and EV-DO over IP
Ericsson	New transport module generally available in 1Q08; supports Abis/IP	New transport module generally available in 1Q08; supports lub/IP	Not relevant
Huawei	Announced first live deployment of Abis/IP in 4Q07	Generally available since 2Q07; supports lub/IP	Generally available since 2Q07; supports 1X and EV-DO over IP
Nokia Siemens	Ethernet since 4Q06 for offload & pseudowire; lub/IP from 4Q08	Abis/IP over Ethernet interface generally available in 1Q08	Not relevant
Nortel	Information not collected	Not relevant	EV-DO support for several years; add 1X support in 2H08

Source: *Unstrung Insider*

The competitive positioning of key vendors is summarized below:

- **Huawei** leads the market in terms of commercially available, native IP RAN and has full support for Ethernet across its base-station portfolio. The vendor has both UMTS (EMobile, Japan) and GSM (China Mobile) reference customers and is successfully marketing its all-IP mobile network vision around the world.
- **Nokia Siemens Networks** has some early customers taking advantage of the built-in Ethernet capability already available on its Flexi WCDMA base stations to enable hybrid backhaul architectures and ATM pseudowires. However, its schedule for native Iub over IP is a little behind key competitors.
- **Ericsson** has the most consistent strategy in the market. While it isn't the first to market, its launch of Ethernet and native IP RAN capability across both its 2G and 3G portfolios in January 2008 will have the largest overall impact on the market – one that will be magnified by the size of Ericsson's installed base.
- Driven by EV-DO rollouts, CDMA operators and vendors have been more aggressive on IP RAN transport than the UMTS community, albeit primarily over T1. **Alcatel-Lucent** and **Nortel** now both offer Ethernet-capable CDMA equipment and anticipate increased demand for "single-pipe" transmission that combines 1X and EV-DO over IP/Ethernet.

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