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TECHNICAL WHITE PAPER

Mobile Broadband Wireless Networks — Today and Tomorrow

Charting the evolution of unlicensed and licensed broadband wireless solutions

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Discussion Points

- Widely-adopted 802.11 Wi-Fi technology provides a logical starting point for deploying a mobile broadband wireless network.
- New enhancements to the 802.11 standard are being developed to increase throughput and support for latency-sensitive network traffic.
- Integrating licensed wireless technologies into a Wi-Fi network enables high-performance backhaul solutions in deployments where fiber runs are not viable.
- Licensed broadband wireless technologies such as WiMAX and TD-CDMA can be deployed in access networks to support low-latency, bandwidth-intensive applications.
- Hybrid unlicensed/licensed spectrum networks are ideal for supporting a wide range of next-generation applications, including video surveillance, emergency response, and public Internet access.

Executive Summary

As the communications industry moves into the 21st century, the deployment of broadband wireless networks is continuing to accelerate. Driven by an industry-wide shift to IP-based packet networks, the widespread adoption of Web-based applications, and the proliferation of digital media, a sharp demand has emerged for a new generation of mobile devices—and broadband technologies to support them. Traditional cellular infrastructures are simply not capable of delivering the bandwidth required by next-generation mobile devices and applications. This lack of capacity is driving worldwide demand for new wireless technologies that can support advanced mobile broadband services.

Ultimately, it's a question of which broadband wireless technologies to deploy—and when. For many, unlicensed outdoor Wi-Fi is an obvious and logical starting point, but new licensed technologies such as WiMAX and TD-CDMA are also available. As a result, service providers and municipalities are facing a number of choices and decisions when selecting broadband wireless technologies. And it's not just an issue of technology selection—deployment and implementation must be based on a sound business model, based on how revenues will be derived from the infrastructure.

This document evaluates the current options for deploying unlicensed and licensed broadband wireless networks, and charts a path designed to maximize technology assets today and into the future.

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Introduction

During the last ten years, the worldwide communications infrastructure has undergone a seismic shift from the time-division multiplexing (TDM)-based telephony architectures of the 20th century to today's IP-based packet networks. This shift, coupled with the broad adoption of the Internet and Web-based applications, is driving the demand for exponential capacity increases for both wireline and wireless networks. When compared with the surging bandwidth demands of streaming multimedia, VoIP, and other next-generation IP applications, the gradual capacity increases of the public switched telephone network (PSTN) are a thing of the past.

Wireline infrastructures worldwide have undergone a major transformation, both at the core and at the user access points on the network edge. In the United States, multi-billion dollar investments are being made by carriers to deliver even more capacity to their packet infrastructures. AT&T's U-verse service is deploying ADSL2+ to create an IPTV network; Verizon is rolling out a fiber optic service—FIOS—to residential customers; and cable operators are upgrading their hybrid fiber/coax (HFC) plants to support two-way packet networks with DOCSIS. In the near future, users of these networks will be provisioned with 20, 30, or even 100 Mbps service, and carriers will be able to market high-revenue broadband IP-based services.

While wireline infrastructures are making significant strides towards delivering high-bandwidth broadband services, cellular infrastructures are lagging behind. The two largest U.S. wireless operators, Verizon and AT&T/Cingular, are currently operating 2.5/3G cellular networks with data services. However, data throughput on these networks is still measured in 100 Kbps increments, significantly less than service offerings on the wireline side. Simply put, legacy cellular networks are not capable of providing the bandwidth demanded by today's mobile devices and applications. This is fueling the development of new broadband wireless technologies purpose-built to address high-bandwidth mobile data requirements. These technologies can be grouped into the following two categories:

- Unlicensed spectrum solutions that are based on Wi-Fi IEEE 802.11 standards
- Licensed spectrum solutions, which currently include WiMAX (802.16 d/e) and TD-CDMA

Existing unlicensed Wi-Fi IEEE 802.11a/b/g networks are capable of supporting a broad range of services, and with new Wi-Fi standards such as 802.11n and 802.11e, Wi-Fi networks will be capable of faster network throughput and enhanced Quality of Service (QoS). By making the Wi-Fi environment more robust, these advances are adding functionality and viability to the already widely-accepted Wi-Fi standard, and providing support for higher-bandwidth applications with more stringent latency and QoS needs. Additionally, as the 802.11r and 802.11s standards for roaming and mesh networking are developed and implemented, outdoor Wi-Fi network solutions will gain additional capabilities for enhanced mobile services.

New licensed spectrum solutions also hold great promise for delivering mobile broadband wireless solutions. WiMAX is based on the IEEE 802.16d/e standards, and is expected to play a key role in the mobile broadband wireless networks of the future. TD-CDMA is a licensed spectrum solution based on the 3GPP family of standards, and is particularly well-suited for provisioning high-speed mobility applications such as public safety or mobile TV. By purchasing the right to exclusive use of licensed spectrum, service providers can create networks that are capable of supporting next-generation telephony and broadband multimedia services. In order to provision these advanced services, mobile wireless bandwidth needs to be brought to the next level of capacity—2, 3, or 4 Mbps initially—and even higher in the near future.

This document focuses on the unlicensed and licensed carrier-class solutions that are currently being offered, and technologies

that will soon be introduced into the marketplace. Operators interested in deploying rural, suburban, or metropolitan broadband wireless networks will be provided with a variety of options. A full range of future-proof solutions that leverage available Wi-Fi technologies will be discussed, and an open migration path to integrating licensed WiMAX and TD-CDMA technologies will be presented.

Outdoor Wi-Fi Solutions

Proven, Robust, and Scalable into the Future

Originally developed as an indoor technology to support wireless connectivity to laptops and other IP-enabled mobile devices, Wi-Fi has rapidly evolved into an outdoor broadband wireless solution. Based on the IEEE 802.11 family of standards, Wi-Fi has been adapted for outdoor networking applications through the use of environmentally-hardened enclosures and the introduction of mesh networking protocols. Early outdoor access points utilized a single 802.11 radio for both client access and mesh networking. While capable of providing basic connectivity, this design experienced significant performance degradation under load.

Today, virtually all outdoor Wi-Fi access points employ multiple radios to allow for independent access and mesh networking operations. And in the case of GO Networks, we go a step further by integrating smart antenna access radios to further maximize RF performance and utilization. This advanced design enables Wi-Fi networks constructed with GO Networks base stations to support a whole new suite of capabilities such as VoIP, video surveillance, and public safety applications with greater performance and better economics.

As soon as outdoor Wi-Fi networks are deployed, either as hotzones or as city-wide installations, they are greeted by a large installed base of Wi-Fi clients. There are literally millions of Wi-Fi enabled users worldwide, and the user base is expanding exponentially. Wi-Fi chipsets are currently being utilized in a wide range of mobile devices, including laptops, phones, tablets, cameras, MP3 players, and with more to come. This large user base, coupled with Wi-Fi's economical use of unlicensed spectrum, makes outdoor Wi-Fi networks a logical starting point for service providers and municipalities to deploy broadband wireless services. And as further developments and enhancements are made to the standard, Wi-Fi will continue to increase in both capabilities and viability.

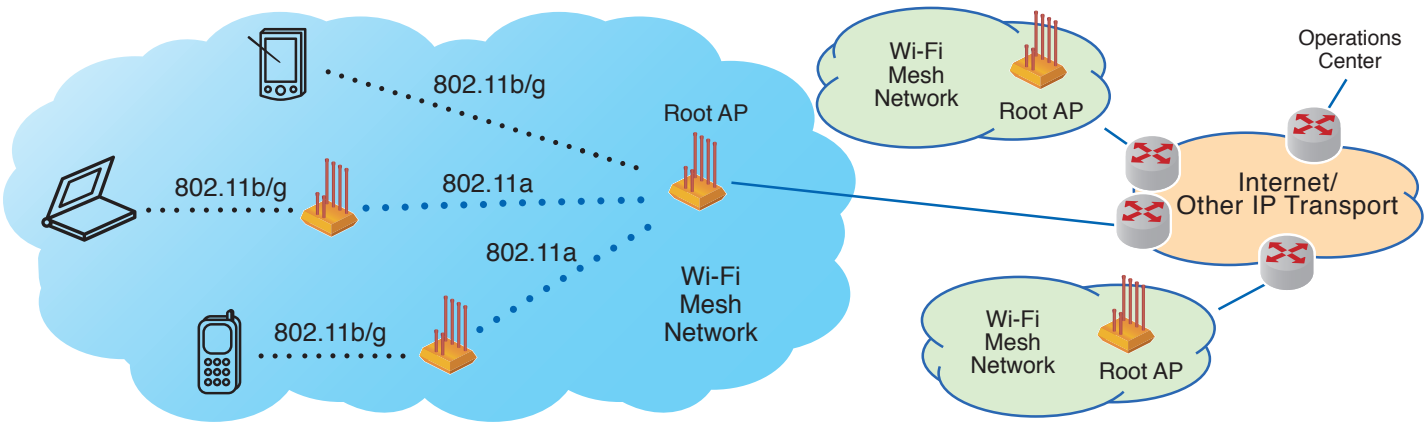

Figure 1: Typical outdoor Wi-Fi mesh network deployment.

Evolution of Outdoor Wi-Fi Networks

As previously discussed, several factors are contributing to Wi-Fi's ongoing viability as a broadband wireless solution. As an unlicensed technology, Wi-Fi does not require spectrum acquisition, providing low entry costs when compared to traditional licensed cellular technologies. And with up to 40 MHz of channel bandwidth, the Wi-Fi technology suite has significant advantages over licensed spectrum solutions that are typically restricted to channel bandwidth in the range of 5-10 MHz.

To address this growing demand for Wi-Fi connectivity worldwide, several new standards are being developed to further extend the capabilities of Wi-Fi networks. These new standards include:

- **802.11n**—Expected to be ratified in the immediate future, 802.11n provides higher data transfer rates of 100 Mbps and greater. Well-suited for enhancing performance by increasing the speed of the mesh topology between multiple base stations, and for supporting higher-bandwidth links to individual users on the network.
- **802.11r**—Being developed to solve the challenges faced by mobile clients as they move between access points on the network. IP telephony requires that this transition be limited to approximately 50 milliseconds, and that the necessary QoS levels are available to support VoIP.
- **802.11s**—The Mesh Networking Task Group (TGs) is currently refining its draft proposal to interconnect access points with peer-to-peer links using the Hybrid Wireless Mesh Protocol.
- **802.11e**—Designed to provide guaranteed QoS levels in a wireless networking environment, this standard is viewed as a key step in providing support for latency-sensitive applications such as VoIP and streaming multimedia.

As evidenced by the intense effort of the working groups, it is apparent that the capabilities of Wi-Fi will continue to expand. The infrastructure that was first designed to support basic applications, such as Web browsing and email, is being refined and enhanced. These refinements will enable the Wi-Fi networks to better support deterministic applications such as VoIP, streaming multimedia, Internet radio, and more—all at carrier-scale. Critical public safety functions, such as emergency response services and video surveillance, are also being migrated to broadband wireless networks. These services can be supported over the unlicensed 2.4 GHz band or the licensed 4.9 GHz band, furthering the need for Wi-Fi based solutions.

Maximizing Outdoor Wi-Fi Performance with GO Networks

While outdoor Wi-Fi networking has many advantages, there are several significant challenges that can undermine an operator's ability to deploy a carrier-class infrastructure. In particular, interference in the highly-saturated unlicensed 2.4 and 5.8 GHz frequency bands poses a very real problem. In-building penetration is another shortfall of typical municipal Wi-Fi networks, as are topographical factors that can cause weak or inconsistent signal coverage. Fortunately, these issues can be successfully addressed by deploying xRF™-enabled GO Networks base stations, which are purpose-built to deliver superior signal strength and significant enhancements in range, capacity, and coverage.

GO Networks understands that when it comes to designing and deploying outdoor Wi-Fi networking solutions, it's simply not enough to weather-protect equipment designed for indoor use. In order to maximize performance and service quality, hardware solutions designed for outdoor use must also be able to adapt to ever-changing RF environments. To meet these demands, GO Networks has introduced an innovative, patent-pending technology known as xRF adaptive beamforming smart antenna technology. Designed to address the interference, range, and capacity issues that can negatively impact outdoor Wi-Fi deployments in the unlicensed 2.4 GHz spectrum, xRF-enabled base stations deliver significant enhancements over earlier-generation access points from other vendors.

On the transmit side, the xRF technology dynamically focuses radio energy towards the client, effectively reducing the amount of multipath the client's receiver is exposed to, and increasing the system's range and throughput. In the U.S., a market regulated by the FCC, xRF allows the GO Networks base stations to operate at an EIRP of up to 42 dBmi — effectively four times the transmit power of conventional Wi-Fi systems. This results in even greater improvements in range, capacity, and throughput across the coverage area.

On the receive side, xRF overcomes the detrimental effects of multipath, where a transmitted signal follows several propagation paths towards the receiver, causing time delay and delay spread that result in higher bit error rates and degraded performance. By constructively combining phase-shifted signals received through reflections, significant improvements to the signal-to-noise ratio (SNR), particularly in multipath-prone non-line-of-sight (NLOS) scenarios, can be realized.

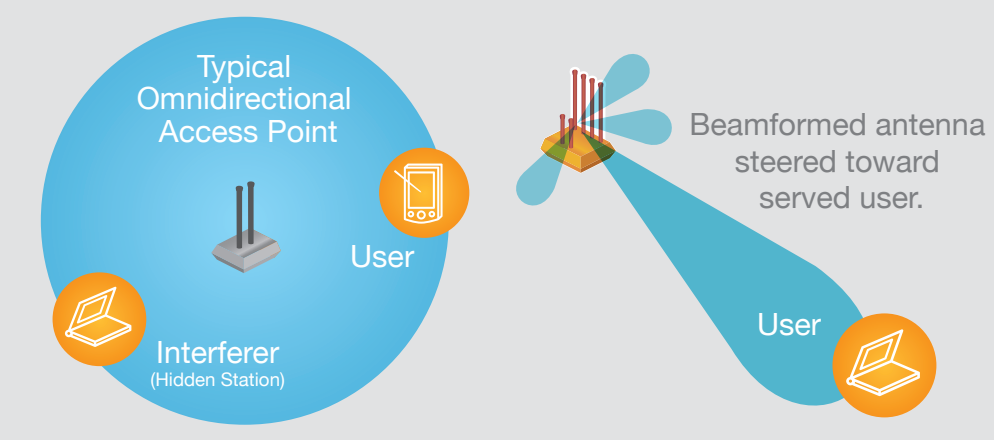

Figure 2: xRF-enabled GO Networks base stations increase signal strength, improve range, capacity, and coverage, and reduce network-crippling interference.

In addition, the directional broadcast pattern of the xRF-enabled base stations produce significantly less inter-cell interference, enabling more scalable, higher-performing mesh networking solutions to be successfully implemented. Collectively, GO Networks Wi-Fi solutions provide a number of critical benefits for maximizing both network performance and economics.

- Delivers significant performance enhancements, including range extension up to 150%, capacity increases up to 400%, and coverage improvements up to 180%
- Reduces upfront CAPEX by up to 50% and recurring OPEX by 30 to 50%
- Enhanced in-building penetration
- Improved non-line-of-sight (NLOS) performance in deployments where foliage and other topographical factors are problematic

GO Networks Mobile Broadband Wireless (MBW) Product Portfolio

GO Networks offers three base station configurations designed to provide connectivity at the micro, pico, and femto level. This flexible solution set enables broadband wireless networks to be deployed with a level of precision that cannot be achieved with solutions offered by other vendors. The product line includes the following models:

- MBW 2000 Micro Cellular-Mesh Wi-Fi Base Station is a 120° multi-radio sector panel designed for building sides, rooftops, towers, and utility poles. The unit is equipped with two xRF-enabled 802.11 b/g access radios for high-performance coverage and a separate 802.11a channel for high-performance mesh networking and backhaul.
- MBW 1000 Pico Cellular-Mesh Wi-Fi Base Station is an omnidirectional multi-radio weatherproof design intended for street-level light/utility pole Wi-Fi applications. The unit is equipped with one xRF-powered 802.11b/g radio for high-performance access and coverage and a separate 802.11a channel for high-performance mesh networking.

Figure 3: The GO Networks Mobile Broadband Wireless (MBW) product family.

- MBW 500 Femto Cellular-Mesh Wi-Fi Base Station is a cost-effective, omnidirectional unit designed for street-level light/utility pole femto cell Wi-Fi applications. Fully weatherproof, the MBW 510 features a multi-radio design with one conventional 802.11b/g radio for subscriber access, and a separate 802.11a channel for high-performance mesh networking.

The GO Networks base stations are fully manageable using the GO Networks MBW EMS/NMS platform, enabling network operators to perform device management and advanced system-wide network and RF optimization in real time.

Introducing licensed spectrum solutions into the Wi-Fi infrastructure

Optimizing Wi-Fi Networks with Next-generation Licensed Wireless Technologies

Licensed Backhaul Solutions

In many instances, operators of outdoor Wi-Fi networks utilize licensed wireless backhaul solutions to provide connectivity from Wi-Fi gateways/root nodes to their core network assets and the Internet. Especially in environments where rolling out fiber is not a viable option, licensed wireless technologies can serve as an alternative to achieve high-bandwidth backhaul and capacity injection. Today, operators can select from a range of wireless technologies for backhaul, including high-bandwidth proprietary microwave solutions and standards-based technologies such as WiMAX or TD-CDMA.

For operators seeking high-bandwidth licensed microwave solutions, Next***Wave*** Wireless and GO Networks partner with DragonWave, a market leader in metro Ethernet and fixed-wireless solutions. The DragonWave solutions are based on proprietary microwave technology that can be configured to operate on a wide range of unlicensed and licensed frequencies, and are ideal for supporting cost-effective backhaul connectivity and capacity injection.

In other cases, operators may elect to use standards-based licensed wireless technologies such as WiMAX and TD-CDMA for backhaul connectivity. Both of these technologies can be very effective for Wi-Fi backhaul and capacity injection, but they also have the added benefit of evolving over time to enable advanced subscriber access services in the future.

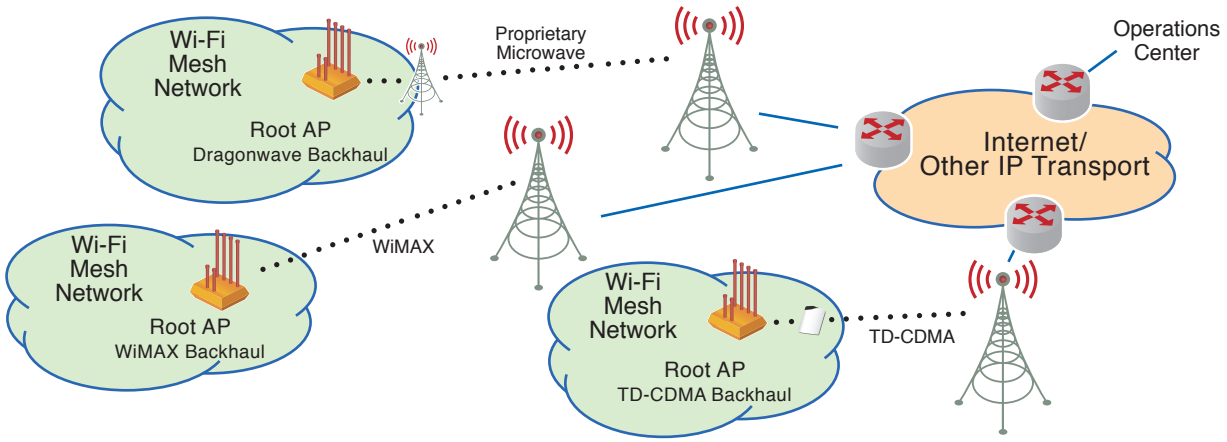

Figure 4: Licensed wireless technologies provide a viable alternative to fiber for backhaul and capacity injection.

Several key benefits are realized by introducing licensed wireless backhaul technologies:

- Reduces initial capital expenditures and operational expenses by limiting costly fiber and copper deployments and/or ongoing leased-line expenditures
- Supports provisioning of service to Wi-Fi access points where wired backhaul is not available
- Proprietary point-to-point microwave solutions deliver high-bandwidth connectivity
- WiMAX and TD-CDMA backhaul solutions provide a smooth migration path for service providers looking to support direct client access in the future

Hybrid Wi-Fi/Licensed Access Solutions

As the industry matures, Wi-Fi networks are increasingly being coupled with licensed access networks. By adding a licensed overlay to the Wi-Fi network, additional opportunities for rolling out high-value IP services are made possible. Although more expensive to deploy and operate, licensed broadband wireless technologies can be more deterministic and better-suited to guarantee higher Quality of Service (QoS) levels. These advanced capabilities have generated considerable interest in deploying hybrid access networks that combine Wi-Fi with existing and emerging licensed technologies such as EDGE, EV-DO, TD-CDMA, WiMAX, and LTE.

Several key advantages are realized by integrating a licensed-access solution into the Wi-Fi environment to create a hybrid access infrastructure. From an RF perspective, licensed solutions provide a dedicated infrastructure that can be tightly controlled and restricted, ensuring that specific QoS thresholds will be maintained. And due to the fact that the spectrum is licensed solely to the operator, interference and bandwidth contention from foreign devices is either sharply reduced or eliminated.

Of the available licensed-access technologies, TD-CDMA and WiMAX are particularly well-suited for integration into Wi-Fi environments. TD-CDMA is ideally suited for supporting services such as public safety and mobile TV, and is deployed using

a cellular architecture that enables it to support vehicular voice traffic at high speeds. As a result, TD-CDMA is being used in conjunction with Wi-Fi to power New York City's emergency response network, the largest public safety installation in the United States. TD-CDMA is also being used to support TDtv, and has been validated by some of Europe's largest UMTS operators. Software-upgradeable to WiMAX, TD-CDMA utilizes unused 3G spectrum to achieve medium-bandwidth licensed connectivity.

WiMAX is a higher-bandwidth solution that is capable of providing seamless coverage over hundreds of square miles. The 802.16e WiMAX standard supports the creation of high-bandwidth mobile wireless networks, and is expected to be widely adopted in the near future. Using this advanced technology, subscribers will have full access to latency-sensitive applications, as well as high-bandwidth Internet connectivity, while traveling across the covered area. Similar to cellular networks, the mobile WiMAX architecture supports transparent handoffs as the subscriber moves from one coverage zone to the next, ensuring a high-quality user experience.

In most cases, TD-CDMA and WiMAX devices also have built-in Wi-Fi connectivity, making hybrid network access solutions that combine the technologies very effective. TD-CDMA and WiMAX are typically introduced into Wi-Fi access networks with macro cell and/or micro cell base stations to provide broad coverage. As coverage requirements and subscriber densities change over time, additional base stations can be deployed at the pico cell and even the indoor femto cell level.

TD-CDMA and WiMAX enable carriers to augment their Wi-Fi access network in several key ways.

- **New services:** With TD-CDMA and WiMAX operators can deliver higher QoS levels, allowing them to roll out new types of overlay applications and services such as business-class voice or mobile TV.

- **In-building penetration:** As licensed technologies, TD-CDMA and WiMAX benefit from better in-building penetration. While Wi-Fi can deliver similar capabilities using GO Networks xRF technology coupled with high-powered customer premises equipment (CPE), TD-CDMA and WiMAX are capable of providing service to handsets and media players inside buildings without additional equipment.

- **High-speed mobility:** TD-CDMA and WiMAX are capable of supporting mobile services at ultra high speed, delivering stable connectivity at velocities up to 200 miles per hour (mph). In contrast, Wi-Fi's ability to support mobile connectivity tops out at approximately 70 mph, making TD-CDMA or WiMAX the logical choices for supporting mobile transit applications at high speed. For example, TD-CDMA or WiMAX can be used to establish high-bandwidth backhaul connectivity for Wi-Fi hotspots deployed in high-speed commuter trains. Inside the train cars, Wi-Fi access points are deployed to provide broadband on-ramps. This approach also enables premium subscribers equipped with PCMCIA/CardBus adapters to connect directly to the TD-CDMA or WiMAX network and access higher-level services.

Clearly, there are a number of advantages to a hybrid broadband wireless architecture. Ultimately, the network composition and services will be dictated by economics and capacity. Licensed wireless access solutions typically are more expensive than Wi-Fi access solutions and there is typically less capacity. As a result, careful planning and business modeling is required to best utilize network resources and maximize revenue potential.

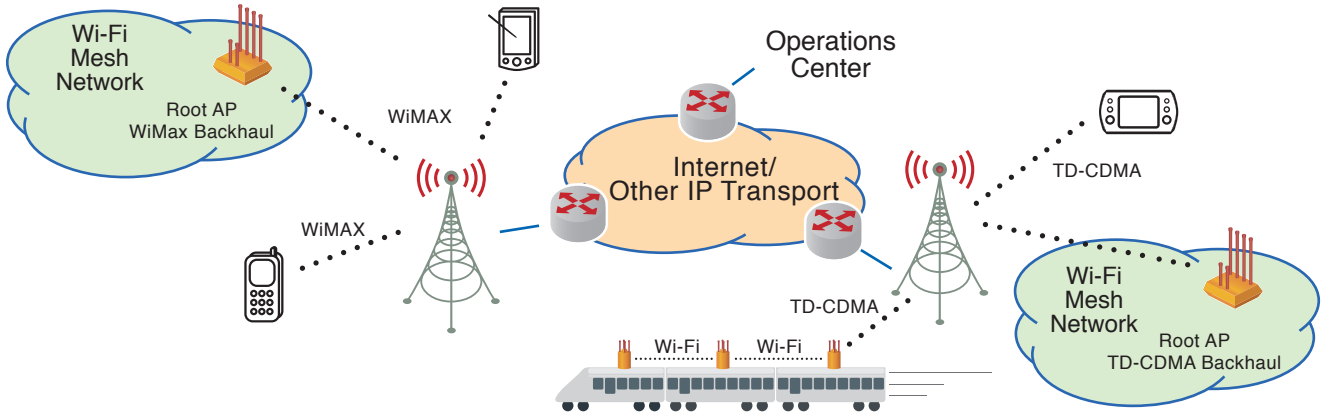

Figure 5: Hybrid Wi-Fi plus TD-CDMA/WiMAX access network.

Conclusion

As technologies evolve, GO Networks and Next***Wave*** Wireless are uniquely positioned to help you build the broadband wireless network that is right for you. Through close collaboration with our customers and extensive research and development, we have gained valuable insights and a fundamental understanding of wireless technologies and networking. We are helping to shape the future—through our development of innovative high-performance Wi-Fi systems, our leadership in TD-CDMA and WiMAX technologies, and our other initiatives to enable 4G multimedia systems and content delivery around the world.

For more information on how your business can benefit from the innovative approaches being developled by GO Networks, please contact us via email at info@gonetworks.com.

About GO Networks

GO Networks, a wholly-owned subsidiary of Next***Wave*** Wireless Inc. (NASDAQ:WAVE), is a global supplier of carrier-class, Mobile Broadband Wireless (MBW) Wi-Fi solutions to commercial and municipal wireless broadband service providers. GO Networks' family of micro, pico, and femto Wi-Fi base stations utilize advanced xRF™ adaptive beamforming smart antenna technology to provide operators the network performance and economics they need to profitably deliver mobile broadband services to customers.

GO Networks is headquartered in Mountain View, CA, U.S.A., and operates a large research and development center in Tel Aviv, Israel. It maintains sales offices in China and Germany. Visit GO Networks at www.gonetworks.com.

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