PERASO | WIRELESS UNLEASHED™

Fixed Wireless Access

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Introduction

Reliable and affordable access to broadband data services is widely recognized as an essential factor for economic and personal development across the globe. Providing universal access and bridging the Digital Divide cannot be achieved with one technology.

Utilization of all available options is required to face diverse geographic, topological, economic and even political hurdles. Fortunately, a range of state-of-the-art terrestrial wireless, fiber and cable as well as satellite technologies are available to meet the challenges faced by the next generation networks which will bring economic, educational and cultural benefits to populations across the globe.

Fixed Wireless in the Network

Fixed wireless systems have provided long-haul telecommunication connectivity for decades across oceans and continents. As the digital era evolved, it became an ideal way to provide data connections, especially for cellular backhaul, when cable infrastructure could not support growth and demand.

Today there is fierce competition between fiber and wireless technologies, and it is important to understand the relative benefits of each and how they can be complementary in modern networks.

At a high level, a data network can be divided into 3 key parts: the core, backhaul and access.

The core consists of switching and routing intelligence that directs traffic. Moving huge amounts of data between key processing hubs is most efficiently done with ultra-broadband fiber.

In the backhaul layer, generally comprised of point-to-point connections, fiber or wireless technologies can make sense. Point-to-point wireless technologies have evolved to support more than 10Gbps and are available on a wide variety microwave, and millimeter frequency bands. When rapid deployment, or access to fiber infrastructure is inhibited by geographic or municipal considerations, wireless links can easily fill the need.

Providing the final step of direct access to customers means distribution of service to many endpoints over a wide area. Population densities can vary from a few houses to hundreds of densely packed apartments per square kilometer.

Peraso's Fixed Wireless Access solutions are highly suitable for the following environments:

- Rural
- Suburban
- Urban
- High Density

Examining practical considerations such as deployment time and cost, as well as geographical and municipal hurdles, power grid stability and even susceptibility to vandalism reveal the benefits offered by wireless network systems.

Licensed vs Unlicensed Bands

Access to a licensed frequency band provides the licensee with assurance that their network operations will be free from interference. But the cost of obtaining a territorial license can be prohibitive for some operators and certainly cuts into to the ROI for any operator.

Unlicensed bands have become a popular alternative for WISPs and private networks, but in the most used sub-6 GHz Wi-Fi bands, the spectrum has become so overcrowded that reliable network services are nearly impossible to provide. Specialized terminals with advanced interference mitigation technology and access to the newly allocated 6 GHz frequencies do tackle the problem, but with the trade-off of more expensive hardware and more frequency coordination requirements.

The 60 GHz band was originally allocated as unlicensed due to the undesirable impact of oxygen absorption in the 57-66 GHz range. Ironically, oxygen absorption, in conjunction with the direction beam pattern provided by beamforming antenna technology, enables, 60 GHz systems realize reasonable link ranges with good frequency reuse characteristics. Furthermore, recent updates to regulations (FCC and EU domains) allow use of high gain antennas and additional spectrum up to 71 GHz, which is not impacted by oxygen. These

changes have enabled practical point-to-point radio links for backhaul up to 20 km, and point-to-multipoint access networks with an 8 km range.

With no interference from conventional Wi-Fi, and low self-interference, the 60 GHz spectrum now offers up to an unprecedented 14 GHz of contiguous spectrum which is, and will remain, clean and clear.

Backhaul Application

Backhaul applications address the transport of bulk data from an aggregation point, such as a Cellular node, Fixed Wireless Distribution Node (DN), Access Point (AP), or Wi-Fi hotspot back to a connection with the core network. Backhaul links can be short, as short as a few kilometers or 10's of kilometers and may include repeater nodes (hops).

With access to spectrum from 66-71 GHz, which has been defined as channels 5 and 6 in IEEE 802.11ad/ay terminology, and the allowed use of dish antennas, 60 GHz offers a low-cost and reasonably compact solution for mid-range back haul up to 20 km. Utilizing a single 2 GHz channel, data throughput up to 2 Gbps can be realized. Utilizing multiple channels or channel aggregation can increase capacity up to the 10 Gbps range. If less capacity is needed, channel bandwidth can be reduced, and the range extended.

Backhaul Deployment

Backhaul deployments are generally simple point-to-point connections between an aggregation point, such as a DN, and a core Point of Presence (PoP). When longer, or non-linear connections are needed, intermediate repeater stages can be added. Peraso's software supports a bridging function to easily allow connection of two radios back-to-back.

Fixed Wireless Access (FWA) Application

FWA networks provide data services to residential and enterprise consumers. They often compete with fiber and cable services or provide access to remote areas where traditional services are not available.

Utilizing unlicensed frequencies, Wireless Internet Service Providers around the world have been able to successfully compete with the major Mobile Network Operators (MNO) who also provide FWA as an adjunct business to their primary mobile service. Utilizing their agility and levering a low overhead cost structure, WISPs have often recognized the benefits in addressing underserved communities and providing a superior quality of customer service.

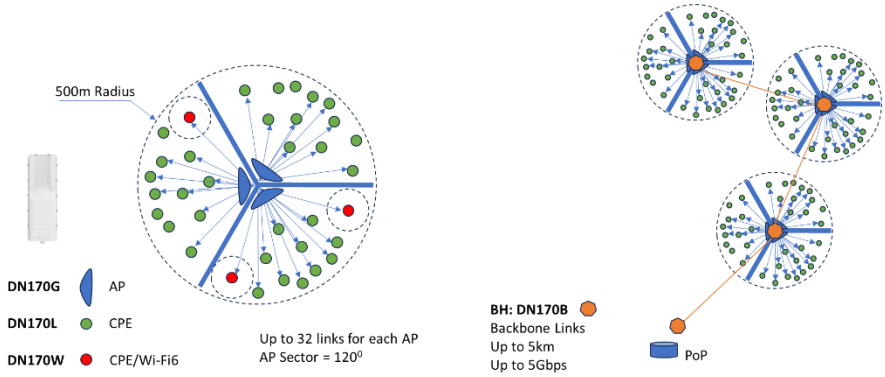
FWA Deployment

There are a few options for deploying FWA networks. The optimal solution can is determined by examining geographic and population density characteristics of a target area.

Topologies

Hub and Spoke / Star

The Hub and Spoke architecture consists of a central Distribution Node which provides service to Customer Premise Equipment (CPE) units. Often several DN units are installed on a common pole or roof top, each servicing a slice, or sector, of the total coverage region. The total data capacity of the DN is distributed among the users in the sector, thus in densely populated areas, it may be desirable to reduce the size of the sector, while sub-urban and rural areas may allow larger sectors. The dimensions of the DN sectors are also related to the gain of the



antenna. Higher gain antennas will generally have a longer range, with a narrower field of view. When designing deployment strategy, it is useful to have a variety of antenna options for both the DN and CPE units.

Extended Hub and Spoke

The Extended Hub and Spoke adds the capability for selecting CPE installations to also act as DN to other downstream CPE. This flexibility allows extending coverage beyond the natural range of the DN and to overcome obstacles, such as tall buildings, which may shadow some customers. This is especially important for high-band microwave and millimeter wave band operation where a clear Line of Sight between the DN and CPE is generally required.

Additional benefits can be derived by adding a few extension nodes into the network. Strategically located nodes can provide redundancy so that no single point of failure will bring down the network. In congested areas, load balancing can be achieved by providing some overlapping DN coverage and allowing CPE to dynamically select the path which has the least load.

Mesh

A mesh is a decentralized network of nodes, where each node can see multiple other nodes. This can be beneficial to building routes that avoid obstacles and allow the network to be highly scalable with built-in redundancy. Network capacity can be increased by adding more PoPs and reconfiguring the routing to utilize the additional connections to the core.

Traffic routing is implemented at every node and decisions are made continuously to maximize network capacity. For multigigabit speed networks, the routing function, and the need to establish multiple RF links at each node, places a burden on the hardware. Multiple RF transceivers and powerful packet routing engines can drive up the CPE node costs.

Planning and Installation of Wireless Network

Modern network planning tools provide an amazing capability to design a network topology for almost any neighborhood or region before ever sending an installation crew to the site. Mapping tools include topographic information and extremely accurate LIDAR 3D data, allowing the planner to pick ideal locations for the DNs and plot the routes to each potential subscriber. Ranges and RF link margins can be easily calculated to help select the right equipment to deploy.

A tower or tall structure is desirable for installation of the Distribution Nodes. Possibly the most time-consuming aspect of network planning is the procurement of permits or access rights for the DN site. Nonetheless, this time is a fraction of the effort and cost of obtaining permits for trenching fiber.

To plan the equipment requirements for the DN locations, an estimate of the number and density of customers is needed. It is also important to understand the potential subscriber growth rate. Each DN unit has a limited number of connections which it can support. It is a good idea to provision enough subscriber capacity to meet expected needs for a few years. Fortunately, mmWave networks are scalable and overlapping sectors can be added in the future, operating on different channels from the original installation. Equipment vendors offer a variety of DN antenna choices to allow tailoring the angular field of view of the sectors, and thus the number of potential subscribers covered.

Once a network is planned and permitted, towers can be constructed in a matter of days by a small crew. When DN radios terminals are installed and provisioned on the core network, there is immediate coverage available to all the customer sites in range.

Installation of most mmWave equipment at a customer site does require a professional experienced with the safe installation of outdoor equipment. The CPE must be pointed at

the DN location. Paraso's Aiming Mode tool provides the installer with feedback to aid in antenna pointing. This process is nearly automatic for short, less than 1 km ranges where automatic beamforming can do all the work. When the range is longer, and a high-gain, narrow beam antenna is used, it may take a few minutes to get the direction dialed in.

Peraso Products

Working with radio equipment provider and engaging directly with WISPs, Peraso has developed a comprehensive set of hardware and software solutions for the mmWave Fixed Wireless Market. Peraso is the only component vendor fully integrated with all in-house developed technology. The core of the hardware solution is Peraso's X720 chipset comprised of a 3 Gbps MAC/PHY IC and the high-power Beamformer RFIC.

Peraso's Perspectus line of integrated modules utilize Peraso's highly efficient and cost-effective embedded antenna designs to provide a choice of antenna gain and field of view to the system designer.

The X720 and Perspectus products are based on the IEEE 802.11ad standard, but Peraso has gone well beyond the core standard to optimize the embedded firmware and host driver-layer software for the Fixed Wireless market. Key features in the Peraso products include:

- Full 60 GHz band coverage 57-71 GHz
- Full, ½ and ¼ channels
- Fractional channel spacing
- Up to 32 DN-CPE connections
- Module antenna gains from 15 to 25 dBi
- Support for add-on dish and lens gain boosters
- USB 3.0 data and control interface
- Peraso API library
- Easy to integrate drivers for Linux based systems including OpenWRT
- Unique network separation techniques
- Load balancing capability
- Aiming mode
- STA focus mode

Conclusion

Peraso pioneered millimeter wave technology for commercial applications and was the first to adapt its 60GHz, beamforming semiconductor products to the Fixed Wireless market. First generation products premiered in 2013 and the latest generation, a high power beamformer supporting the entire 57 to 71 GHz range entered the market in 2019. To date, over 500,000 products based on Peraso multi-gigabit MAC/PHY and RFIC chipset, as well as integrated modules have entered the market.

Peraso continues to evolve its hardware and software to meet market demands and provide the core technology supporting true, multi-gigabit solutions that can be deployed quickly, reliably, with low start up and operating costs.

About Peraso

Peraso Inc. (NASDAQ: PRSO) is a pioneer in high-performance 60 GHz unlicensed wireless technology, offering chipsets, antenna modules, software and IP. Peraso supports a variety of applications, including tactical communications, fixed wireless access, immersive video and factory automation. For additional information, please visit www.perasoinc.com.