LINDSAY BROADBAND

Solving Wireless Backhaul "Router to Tower" Issues

HOW CWDM CAN ELIMINATE CELL BACKHAUL BANDWIDTH BOTTLENECKS

BY DR. FRANCIS NEDVIDEK AND DAVID ATMAN

One of the most urgent issues facing broadband wireline network operators concerns the dramatic acceleration of mobile data traffic growth. Driven by the explosion of smart phones and mobile computing and bolstered by burgeoning wireless bandwidth from 4G, LTE and WiMax deployments, the capacities of existing wireless backhaul links around the globe are becoming overwhelmed.

This avalanche of mobile traffic is exposing a network vulnerability. The wireline-based infrastructure used to backhaul this traffic is ill equipped to handle the rising volumes of traffic from tower to router. The first-mile "tower to the router" link has become a major bottleneck because of two issues.

First, there is the classic fiber exhaust issue of simply not enough fiber capacity to accommodate the increasing number of gigabit and 10G links. The second weakness relates to the fact that many wireless carriers either desire or require dedicated links through network operators' connectivity; they may even demand dedicated backhaul fiber strands connecting access and core meshes with mobile tower sites.

This article examines first-mile fiber challenges from several angles. First, after surveying the options for serving this part of the network, it underscores the advantages of CWDM. Second, it looks the variables involved in upgrading backhaul architectures. Third, it offers two examples for using CWDM to expand fiber capacity while eliminating network elements. Finally, it looks at the CWDM's ability to create virtual fibers and increase wireless capacity.

THE VALUE OF CWDM

One principle of philosophy—and network design—that guides the authors of this article is Occam's Razor, which states that the simplest solution, other things being equal, is the best among more complex solution. Before considering which technology option best solves the "tower to the router" problem, let's take a moment to list the requirements that operators must satisfy in their first-mile backhaul networks:

- Segregation of bandwidth on a per-wireless carrier basis, according to SLAS
- Guaranteed bandwidth of up to 10 Gbps per first mile backhaul link
- Uncomplicated and reliable operation (truck roll avoidance)
- Provisioning simplicity
- Reach of up to 80 km "tower to the router" first mile, but typically much less
- Outside plant environmental hardening
- Facility to preserve undisturbed legacy 1550 nm or 1310 nm fixed connections

The technology options for this portion of the network include active optical networking, passive DWDM and passive CWDM. Let's look at each in turn. Active optical networking is one approach to mitigate wireless backhaul congestion. Analysis demonstrates, however, that in the vast majority of situations and growth scenarios deployment of active equipment amounts to overkill. The complexity of active solutions presents an abundant superset of features and functionality. The operator pays for these functions in hardware costs, software licensing, ongoing maintenance, electrical power and upgrade costs. Segregating or partitioning bandwidth is done at a logical level within the realm of the active electronics.

These higher-level logical approaches, which use layers 2 and 3, for example, yield only best-effort bandwidth performance when emulating individual physical connections. Electrical supply power is another potentially significant expense. In some environments, just routing electrical power to the active optical equipment location may prove a challenging and costly issue. Costs related to training personnel to maintain and manage proprietary network gear and the associated operating, spare-stocking and repair costs further diminish return on investment. Active optical equipment is always best placed in close proximity to the network core; unsophisticated and low-cost passive gear belongs in the access and middle mile networks.

Another approach is passive DWDM networking. Similar to passive CWDM, this represents a more practical option. Where the total number of connections or channels exceeds sixteen (the effective limit of CWDM over legacy fiber exhibiting a water absorption peak) rendering transmission capacity of up to 160 Gbps (or 10 Gbps x 16), DWDM technology may offer viable alternatives. But operators considering DWDM should be aware that it is inherently a more expensive technology and simply will not accommodate the plethora of form factors, from pedestal to line card to CO rack, that characterize this first-mile of the network. In that light, it compares unfavorably with highly adaptable and retrofit-able CWDM schemes. CWDM, indeed, provides an optimal balance between right-sized functionality and right-sized cost, thus satisfying the best-fit rule of Occam's razor. CWDM exemplifies the "granddaddy" of fiber equipment that expands capacity of existing fiber infrastructure by making individual fibers function as multiple optical links, each effortlessly countenancing at least 10 Gbps over spans of up to 80 km. CWDM is unique in its capability to support legacy 1310 nm and 1550 nm single fiber connections while permitting additional CWDM links via the same fiber pair. Both DWDM and CWDM physically partition connections at the physical layer. In other words, a partitioned 10G connection in passive CWDM and DWDM in fact provides a unique and exclusive optical connection for each individual 10Gbps traffic channel.

The flexibility of CWDM also factors into planning and designing cell cite capacity, especially when an architecture is expected to support capacity growth in the long-term. CWDM furnishes a multiplicity of possibilities to upgrade, segregate, partition, overlay, partition, and cascade DWDM over CWDM. For example, migrating Base Transceiver Stations (BTS) to Remote Radio Head (RRH) topologies and/or otherwise expanding and crafting future-proof backhaul links is today a routine part of the challenge. Existing legacy fiber network does not constrain CWDM. Rather, previously deployed and newly introduced channels are handled similarly; they are relayed and routed undisturbed. In that sense, CWDM provides the simplest, most robust and yet most multifaceted option for future expansion, whether addressing a) capacity growth of existing carriers, b) bandwidth expansion of established customers with additional new carriers and subscribers or c) both. Passive CWDM realizes a minimalist approach to solving the problem – only as much as you need, when you need it, without expensive or unnecessary extras.

UPGRADING BACKHAUL ARCHITECTURES

The depiction below represents a typical Radio Access Network (RAN) Outside Plant (OSP) backhaul network. (See **Figure 1**.) The feeder cable often extends several km from the Central Office (CO) or aggregation point to a Remote Terminal (RT) in the vicinity of the wireless tower or cell cite. In such situations it is not uncommon to be confronted with an existing link comprising only a limited number of 6, 8 of 12 fiber strands with electrical supply lines accommodating the optical cable along the same trench.

The link of **Figure 1** transitions to twisted pair or coax beyond the Radio Network Controller (RNC) carrying mobile telephone and community microwave relay services. WiMax and other private dedicated or industrial and security antennas may be co-located at the tower. An individual operator may own the infrastructure and/or fiber; an operator or third-party enterprise may be leasing the tower infrastructure.

It is relatively easy to expand legacy installed fiber that is adequately supplying wireless low bandwidth 2G and some 3G services by upgrading the speeds of CO and RT transceivers or by adding blocks of four wavelengths of CWDM channels. However, bandwidth-hungry 4G and LTE services in most cases will require expansion of optical bandwidth of the CO/RT link and very possibly require converting the RT and distribution terminal (DT) links and the coax tower drops to fiber links, as well. Whether installing twisted pair, coax, electrical power grid or fiber, trenching and duct engineering comprise the majority of costs associated with laying and upgrading additional physical cables. Thus, when the opportunity arises, laying flexible and future-proof optical cable yields a very high ROI whenever trench or conduit infrastructure excavation becomes a consideration, as in **Figure 2** on the next page.

Where operators deploy fiber cable, they typically select larger cables (48+ strands) because the number of the optical strands in the cable does not excessively impact overall project cost. Future capacity restrictions in this way may become virtually eliminated beyond the DT, with the bottleneck shifting to the backhaul feed link. By the same token, the business case for upgrading the CO to RT link (middle mile) part of the OSP using CWDM wins handsomely over any option involving retrenching. Obviously, the longer the trench span, the greater the comparative cost advantage of deploying CWDM.

Figure 1

Low-bandwidth fiber + wireline mobile backhaul example

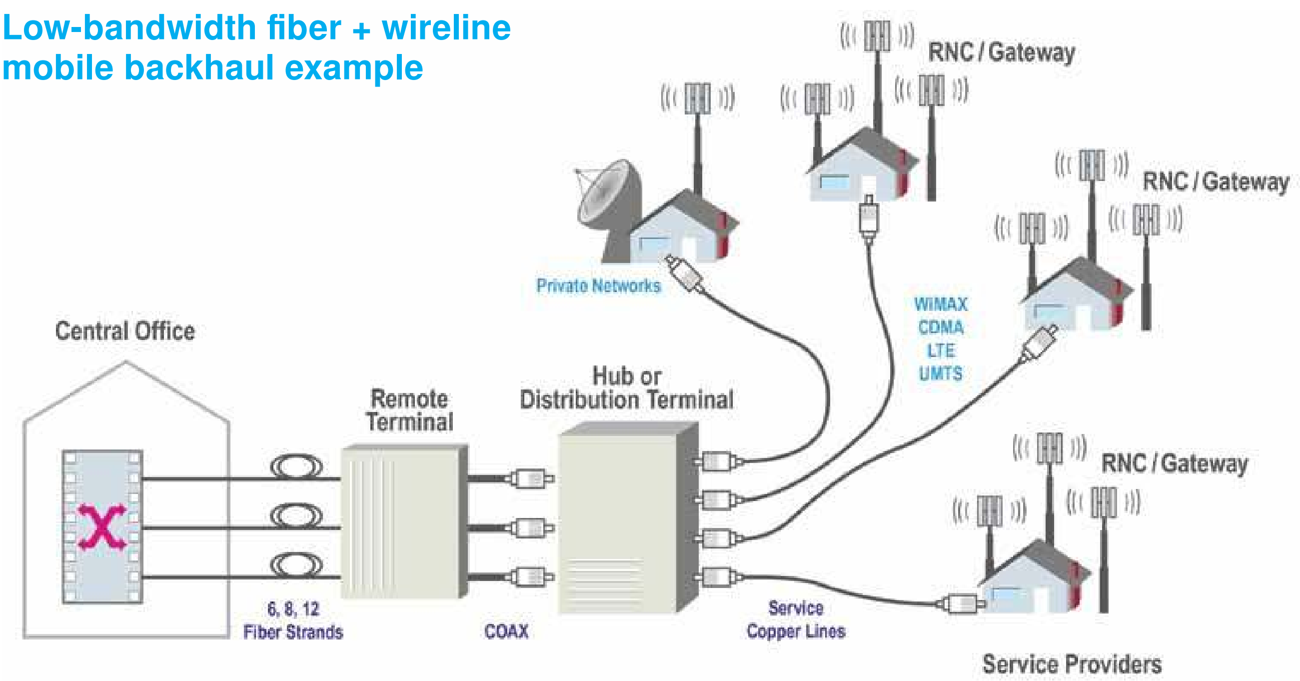
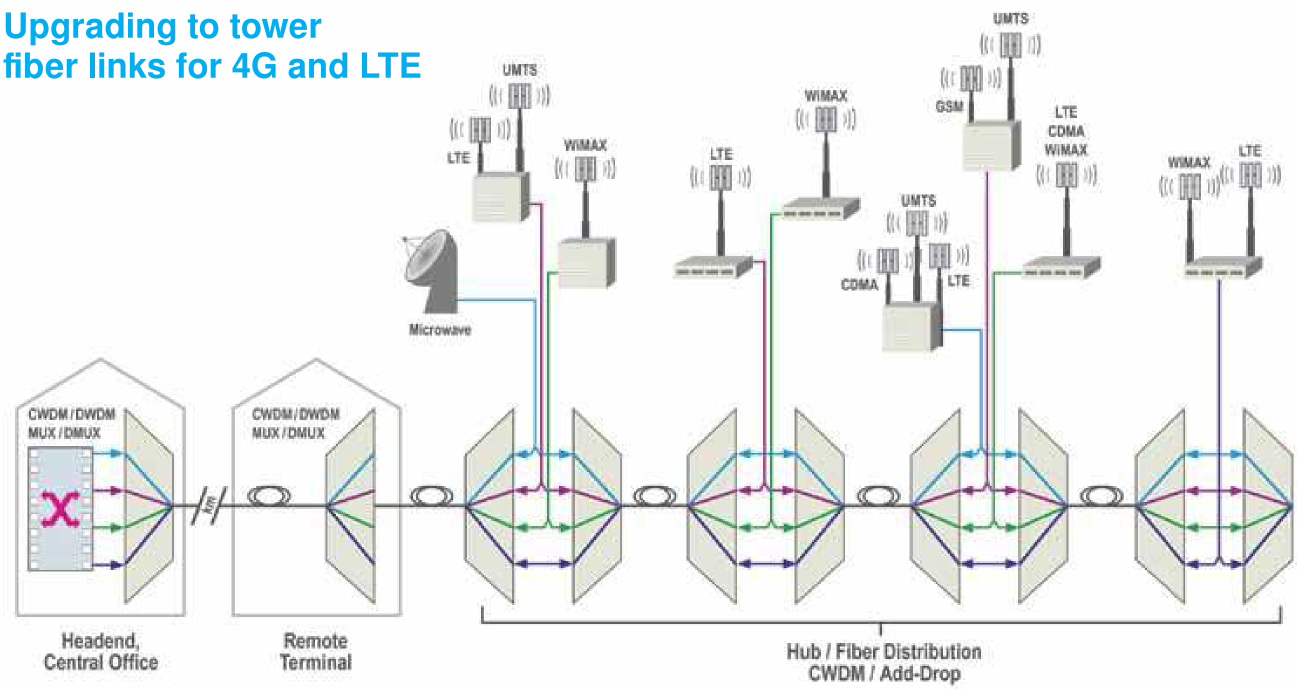


Figure 2

Upgrading to tower fiber links for 4G and LTE



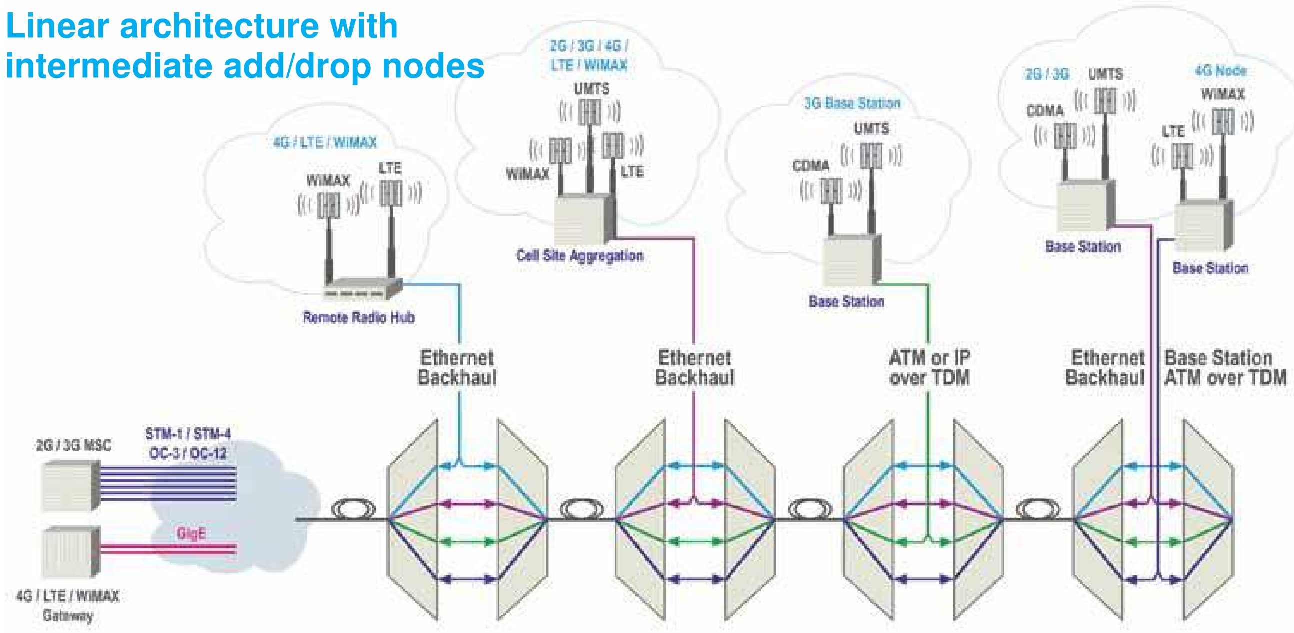
CAPACITY EXPANSION AND LIMITS

Boosting the capacity from the CO straight through to the DT using WDM can easily multiply the bandwidth to the existing DT fibers, while eliminating the Remote Terminal (RT) in the process. Two scenarios enabling efficiencies involve connecting with Wireless Service Providers (WSPs) and linking up series of cell sites. Not all configurations, however, are amenable to these kinds of upgrades. The first scheme increases fiber capacity from the CO to the DT, but also extends the CWDM channels all the way to the WSPs. There is ample fiber in the new fiber cable to permit dedicated fibers running from the CWDM enclosure right through to the multiplexers belonging to each WSP. When several WSPs share facilities at each tower, individual gear may be compartmentalized into a so-called base station hotel, or fibers may run directly to towers outfitted with Remote Radio Head (RRH) technology.

Another architecture taking advantage of CWDM consists of a stitching a series of cell sites along a fiber (four in this case) using the add/drop capabilities of CWDM. One such example is shown in **Figure 3**. Here a CO serves four cell sites with four pairs of wavelengths. A wavelength pair is added or dropped at each cell site. The cell sites may reside tens of kilometers from the CO so that minimizing insertion loss and selecting the appropriate optical power of transceivers becomes an essential priority. Individual cell nodes may be housed in pedestals, small cabinets or even suspended or buried pods. Fusion splicing is often the preferred means of connecting the gear, although connector-fitted solutions perform equally well – link loss margins permitting.

Figure 3

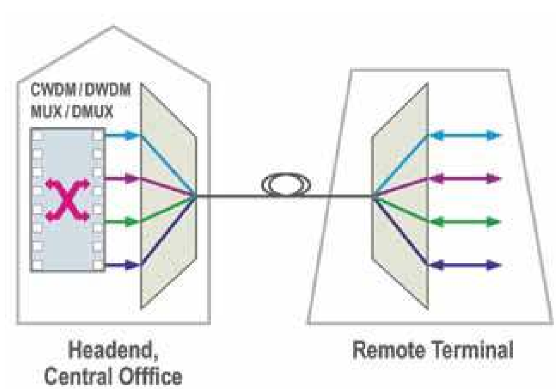
Linear architecture with intermediate add/drop nodes



Depending on the particular regulatory situation or jurisdiction, not all imaginable WDM upgrade configurations may be practicable. First, telecommunications regulations may prohibit certain digital multiplexing of data or channels from particular subscribers (state institutions, security and emergency services, financial networks etc.) Other subscribers traditionally prefer dedicated fiber strands to guarantee privacy and internal network integrity. Circumstances stipulating dedicated fiber(s) may be effortlessly accommodated through consigning WDM capacity upgrade or other fiber strands.

Figure 4

Using CWDM for the critical sections



Furthermore, network reliability and incorruptibility considerations typically arise with respect to latency. Networks transporting SONET overhead or frame relay or pseudo wire protocols strive to eliminate, by all means possible, delays resulting from provisioning, queuing, buffering, switching or other electronic processing. Of course, WDM technologies offer one of the most effective approaches to minimizing latency, because end-to-end delays are essentially reduced to the speed of propagation of the optical signal through the optical link. In a vast majority of deployments, channels allocated via wavelength easily satisfy customers' QoS metrics. Virtual fibers, wireless capacity

An alternative architecture uses CWDM multiplexers to partition a single fiber strand (or pair) and in effect create virtual fibers. CWDM multiplexers are placed at the CO and in a remote enclosure, as depicted in **Figure 4**.

A CWDM system uses 1 to 16 wavelengths based on the ITU-T standard grid (and 2 more channels of the full ITU complement of 18 channels if low "water peak" fiber has been deployed). The transmission equipment at the cell site (DS-1, SONET, Ethernet) can utilize CWDM small form-factor pluggable (SFP) transceivers. If not the case, separate CWDM transponders may convert low power 1310 nm signals to the desired CWDM wavelength. CWDM SFPs and transponders, which support loss budgets of up to 28+ dB, reliably span fiber transmission ranges distances 60 km or even more, depending again on the characteristic of the legacy fiber deployed. A CWDM system can characteristically scale as capacity demand from the wireless subscribers grows.

Additional wavelengths can be made available to particular wireless sites in anticipation of "lighting up" addition wavelengths. Typically a range of flexibility in terms of transmission rate per wavelength permits wireless providers to increase bandwidth to particular cell sites from say 1G to 10G fully independent of the WDM equipment. Alternatively, link capacity may be added by adding or dropping more wavelengths. Boosting capacity of the OSP infrastructure using CWDM technology adequately relieves wireless bandwidth bottlenecks in a vast majority of cases. But for situations where 18 CWDM channels do not suffice, overlaying DWDM wavelengths onto the CWDM grid permits a further and dramatic expansion of transmission capacity.

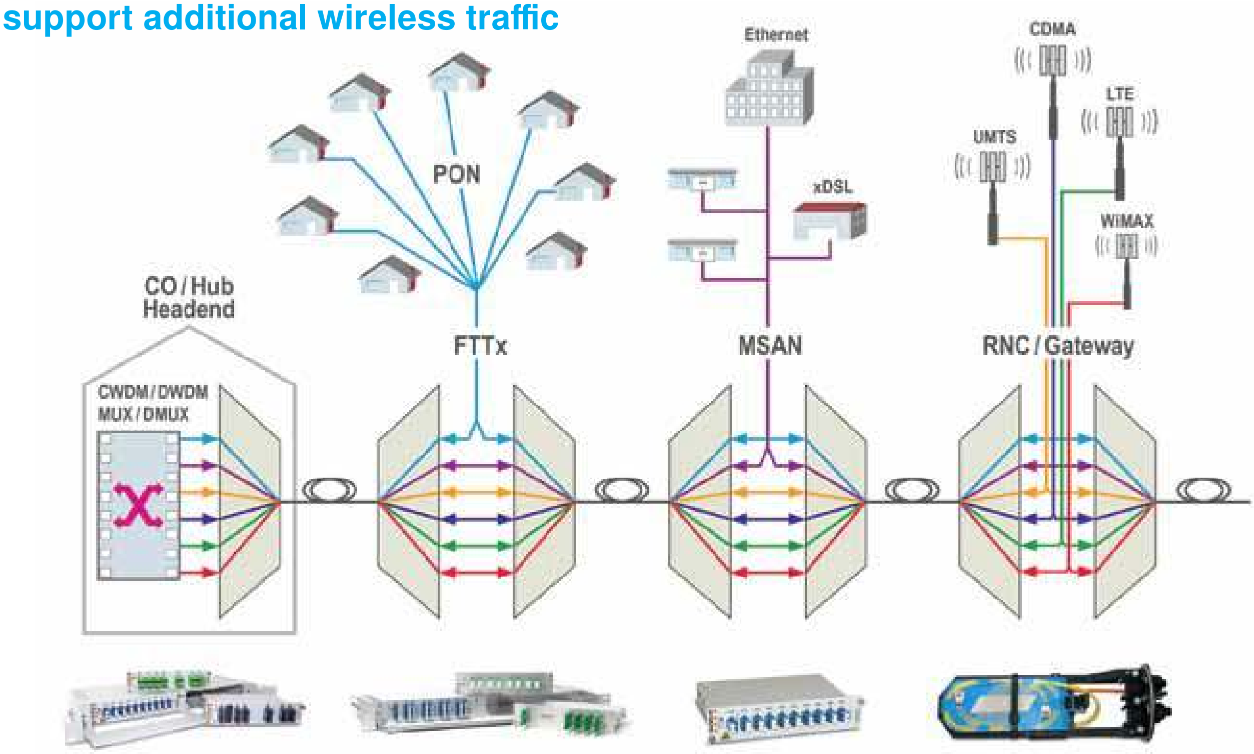
The option to adopt DWDM connectivity however carries the attendant need for controlled environment enclosures and deployment of the appropriate (more costly) DWDM transceivers. Also necessary for DWDM upgrades or deployments is the electrical power to supply the additional equipment and thermal regulation. Need for supplementary space may well arise in RTs introducing DWDM add/drop locations.

Finally, existing access networks may be required to add wireless capacity where the network subscription areas overlap with cell phone, same service provider WiMax and even microwave and private wireless footprints. In such circumstances operational continuity and integrity of the legacy subscription base must be maintained while augmenting bandwidth to individual wireless sites.

Figure 5 demonstrates such a situation. The network segment of here typically comprises part of a ring in urban areas, but the topology often branches to a linear topology in rural or remotely populated areas. Both configurations are possible where new wireless capacity supplements the existing 10 Gbps connectivity linking subdivisions, enterprises and institutions to the co-locations, distribution hub and headend.

Figure 5

Upgrade of existing access network to support additional wireless traffic



CONCLUSION

The rising tide of wireless backhaul traffic is creating bottlenecks in the wireline networks that serve them. CWDM relieves backhaul bandwidth exhaustion in essentially perfect harmony with the dictum that the simplest choice, all things being equal, tends to be the best. Applicable in a range of scenarios, CWDM also demonstrates that flexibility—especially when combined with highly reliable, customizable and compact, low-cost components—is another of CWDM's admirable qualities. CWDM is poised to remedy the vulnerable first-mile, tower-to-the-router backhaul link.

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