Increase localized peak capacity by 50% with mm-wave repeaters

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MOBILE EXPERTS

BACKGROUND:

All mobile networks—and in fact, all wired networks--are designed with extra capacity. The concept of 'overprovisioning' has become standard practice because the data demand in a network is spotty and unpredictable. Because the network planning can never perfectly predict the location of data traffic, the entire network must include quite a bit of extra capacity.

In a recent white paper, Repeaters Cut mm-wave Costs in Half, we examined the cost savings that are inherent in the use of repeaters for mm-wave networks. This white paper assumed the same level of overprovisioning for a fiber-based mm-wave network and a mm-wave network including repeaters. Our previous conclusion was that, using this conservative assumption, a repeater-based network can save roughly half of the cost associated with building and running the network. In this white paper, we look one step deeper, to understand the impact of using repeaters in a flexible 'mesh' architecture instead of fiber backhaul. The implications in terms of total capacity deployed and the efficiency of the network are considered here.

Our previous white paper concluded that repeaters can cut the cost of mm-wave networks in half. Download it here.

Operators 'over-provision' (buy extra radio equipment) because data is unpredictable

OVERPROVISIONING:

Mobile operators typically build their networks with 10:1 or even 20:1 overprovisioning, which means that they calculate the peak-hour demand expected in the network, and they multiply by a factor of 10 or 20 to determine the actual level of capacity to be deployed.

Many factors create inefficiency in the network, requiring the operators to over-invest in this way:

A network of meshed repeaters can reduce the need for overprovisioning.

- **Traffic is 'spotty'.** Traffic patterns vary geographically, with many users converging randomly so that a single radio site experiences variation in the demand. Note that larger areas/greater numbers of users will result in lower variation, and highly localized radio sites will see higher variation. An airport is a good example: the gates may be crowded, but the parking lot is not. We estimate that geographical variations will drive over-provisioning of at least 3:1 in a mature mm-wave network.

- **Traffic is 'peaky'.** Human events can drive spikes in peak demand in very localized ways. A traffic accident or a political protest can create an instant hotspot as dozens of bystanders begin filming and posting videos. In this way, traffic for a single radio site can vary by 100:1 or more. Most of this variation is already accounted for in the industry's common understanding of 'peak-hour' traffic, where the traffic demand is averaged over the busiest hour of the day. However, within the busy hour, the statistical variation in traffic remains significant, with at least 5:1 spikes coming from time-based variation within the busy hour alone.

- **Non-ideal radio conditions** result in modulation/coding choices below the peak level for many users. This factor is most closely related to link budget factors such as propagation losses, penetration losses, and interference.

Over-provisioning is expensive! An operator is forced to buy 10-20X as much radio equipment as their theoretical model would suggest.

The result of these factors: the net effective capacity is only 5-10% of the theoretical capacity of a radio. This becomes an issue for the business proposition, as the operator is forced to buy 10-20x as much radio equipment as a theoretical model would suggest.

This over-investment in capacity can be extremely expensive, especially in the case of mm-wave networks where the coverage area of each gNB is small.

REPEATER MESH:

In a network with repeaters or Integrated Access and Backhaul (IAB), the basic concept of a 'mesh network' can be utilized to reduce the need for overprovisioning. Essentially, the wireless backhaul for each transmission point allows the network to add capacity in a specific location for any period of time.

In this first diagram, we show a grid of gNodeB installations on streetlights, along with repeaters scattered in an office park, a school, and a residential neighborhood.

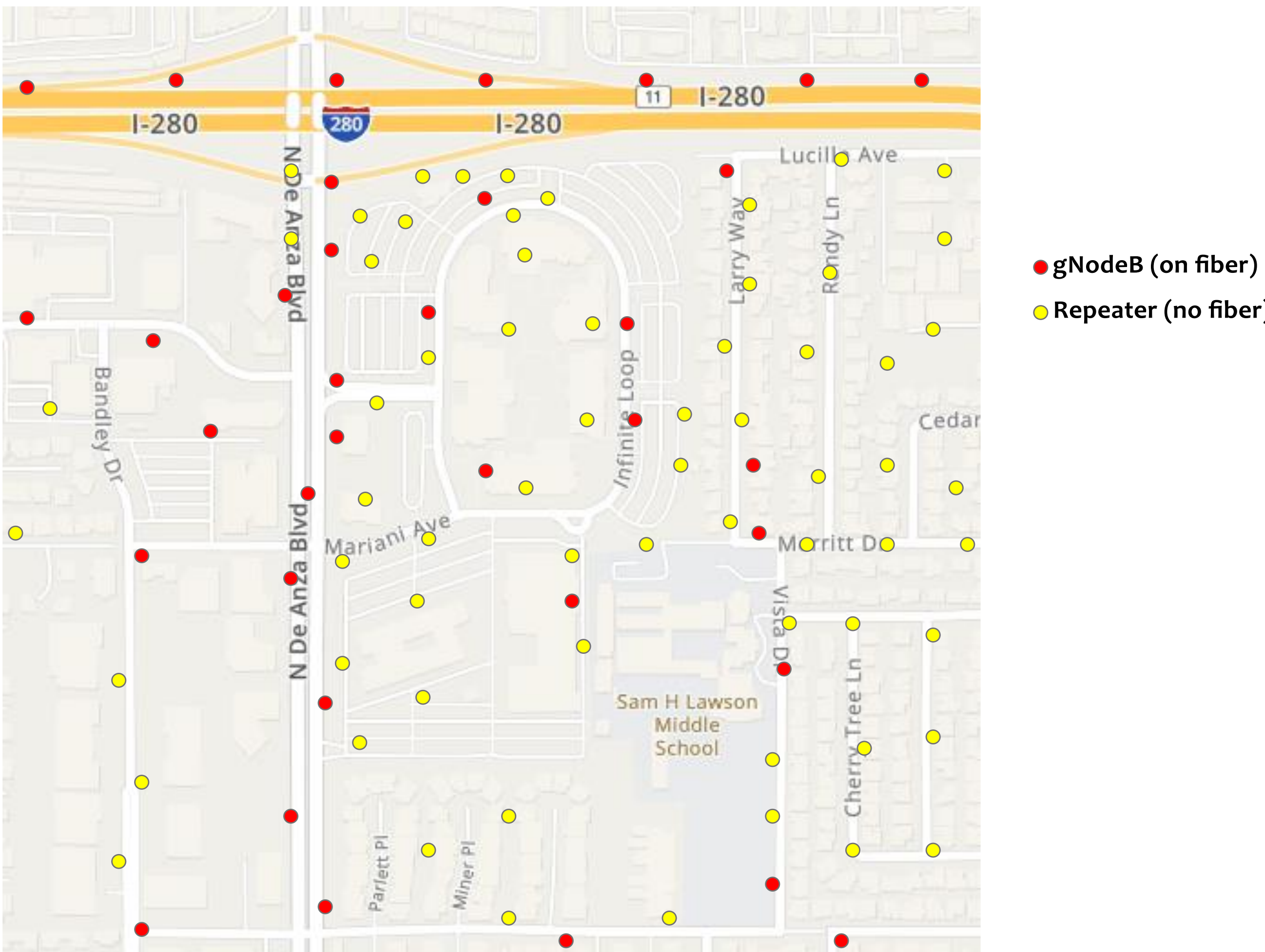

Figure 1: A mesh of gNodeB radios and repeaters in a mixed suburban area

Source: Mobile Experts

Our second diagram illustrates the donor link configurations for the repeaters at noon, when the office workers move to a local restaurant and the kids congregate in the school cafeteria. At the same time, the office workers are using 5G FWA to upload a large file. In these locations, capacity is added to repeaters from gNodeB units one or two hops away, to leave available capacity on the closest gNodeB.

The red circles indicate groups of users at the restaurant, the school quad, and other lunchtime hangouts.

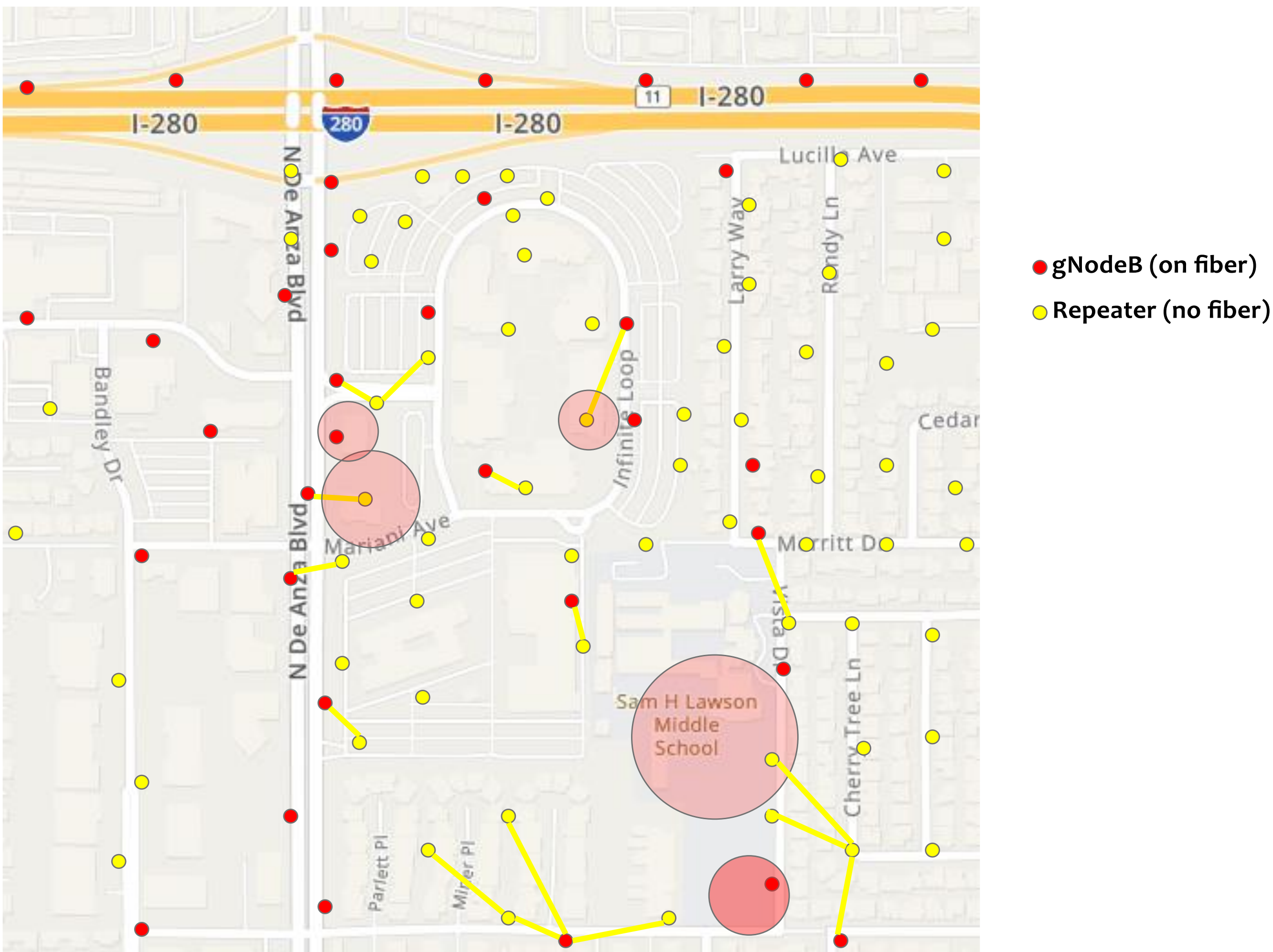

Figure 2: Repeater and gNodeB relationships at noon

Source: Mobile Experts

Next, around 5pm (Figure 3) the office workers are drinking beer in the local bar, the kids have finished band practice and are standing in front of the school, and the donor links have shifted to a different group of gNodeB donors, in order to maximize capacity in new locations. Notice that the bar on DeAnza Blvd. is now serviced by the capacity derived from 6 gNodeBs, instead of only 3 or 4.

In this figure, the red areas denote clusters of users at the bar, on the freeway, and at the school exits.

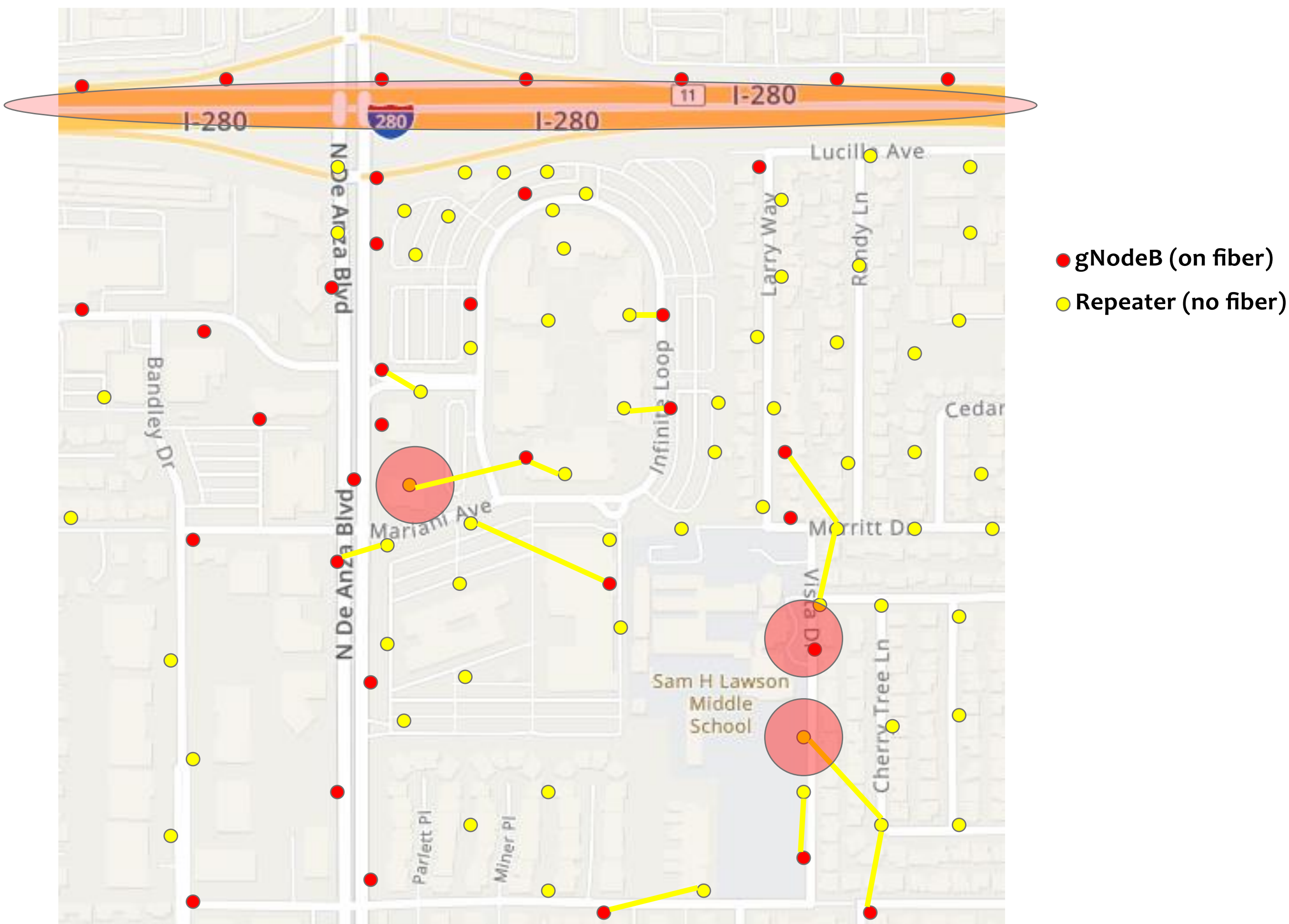

Figure 3:   Repeater and gNodeB relationships at 5pm

Source: Mobile Experts

Finally, around 8pm (Figure 4), the demand has shifted to the apartment buildings and homes in the neighborhood, so the gNodeB donors that previously serviced the offices and school can pivot to service the residential area. The four gNodeBs that had previously focused their capacity at the front of the school are now contributing capacity into the neighborhoods.

Here, the red circles denote clusters of users, now positioned at nearby apartments and homes.

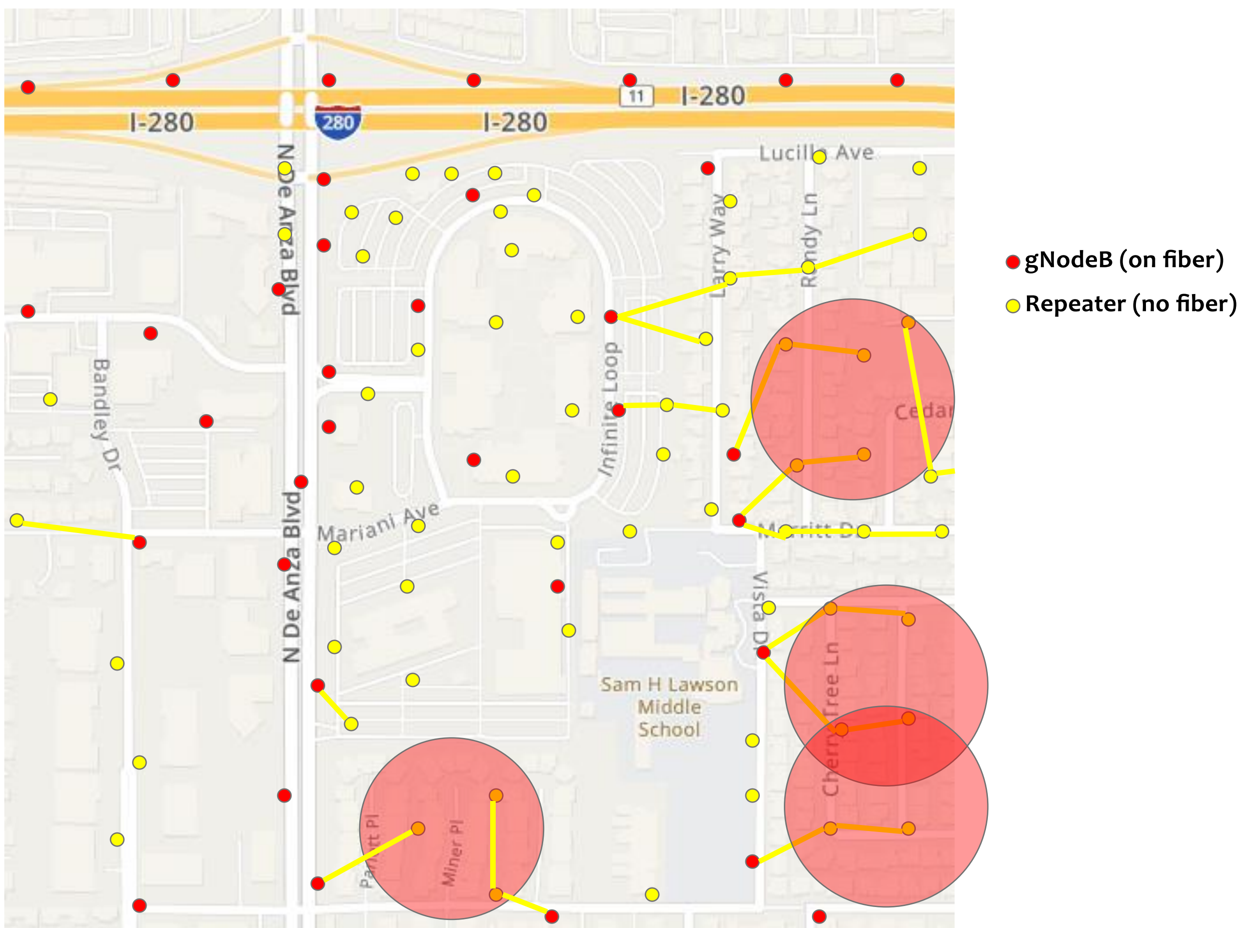

Figure 4: Repeater and gNodeB relationships at 8pm

Source: Mobile Experts

CAPACITY IMPACT

As we examine the bar, the school, and the residential homes in this series, we see that ***the number of gNodeBs contributing capacity in a specific hotspot can double or even more***. Assuming that each gNodeB only 'donates' about half of its available capacity, this translates into a localized boost in capacity of about 50% for the hotspot. This concept deserves a series of thorough field trials to quantify the actual benefit… but we are comfortable that a 50% increase of localized peak capacity is realistic, in the suburban scenario we studied.

The distances, terrain, and foliage are key to determining just how much benefit the operator can squeeze out of the repeaters. In this scenario, we based the spacing of gNodeB units and repeaters on an existing mm-wave network and estimated the possible donor links based on field testing. In an urban environment with large concrete buildings, the benefit could possibly be higher; and in a rural environment we would expect less flexibility in link configurations.

CONCLUSION

The layout of gNodeB radios is typically based on fiber and is set in a fixed position. But the overlay of a repeater grid to extend the gNodeB capacity can introduce dramatic flexibility. This approach mitigates one of the variables in the operator's overprovisioning plan.

Mobile operators can choose to use the benefit in two different ways: They can reduce the overprovisioning that they build into their deployment plans: 10:1 overprovisioning can be improved to roughly 7:1. In short, they could deploy 30% fewer gNodeB units and rely on repeaters to take care of demand.

Another option will be for mobile operators to delay long-term investments in additional capacity. They may deploy a dense grid of gNodeBs in the early days for continuous coverage, but then add repeaters to help that capacity to 'flex' toward localized hotspots. This would defer the ongoing investment in fiber and expensive gNodeB hardware in the future.

Using the flexibility of repeaters, an operator can deploy 30% fewer gNodeB units and/or delay long-term investments in additional capacity.

Remember the "Cell on Wheels" (COW)? With a mesh of repeaters, the operator can move their capacity around… without the wheels.