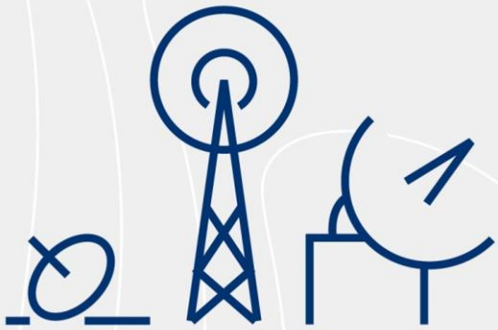
TECHNICAL BRIEF



Mythbusting

Cellular Backhaul over Satellite: MF-TDMA or SCPC

Boundless Communications

Gilat

Introduction

Satellite industry professionals often debate the proper criteria for selecting optimal access technology for satellite applications. It is widely accepted that for large-scale consumer broadband and enterprise networking applications, you are better off with Time Division Multiplexing (TDM) for the outbound and Multi-Frequency Time Division Multiple Access (MF-TDMA) for the inbound. It is likewise accepted that trunking applications are best served with Single Channel Per Carrier (SCPC). In between, there are several scenarios and applications that attract attention and generate commotion. This paper will focus on how to select the right access technology for mobile backhaul applications and the myth of cellular traffic patterns.

As is often the case in debates such as this, the right answer is – it depends. In this paper we will evaluate two common use cases:

1. Rural 3G network (based on a real network of 40 small cells)
2. Remote public safety communications (based on an incident traffic analysis)

What is it going to be? SCPC, MF-TDMA or both? We decided to check!

For each of these defined cases we analyzed the different scenarios and quantitatively compared alternative technologies where applicable. As industry consensus is to use standard-based TDM in the outbound, our discussion will focus on the inbound. We hope this technical brief will assist in determining the appropriate technology for each scenario's projected traffic patterns.

Rural Small Cells

Universal Service Offerings (USO), which mandate broadband delivery to underserved areas, rely on cost-effective rural small cell deployment to battle the growing digital divide. This case is about 2G/3G/LTE backhaul over satellite solution. The scenario involves planning and operating a small rural cellular network. Moving forward, these solutions would also enable rural broadband with LTE, as there is no justification to trench new fiber or copper in some of those remote areas.

The Myth:

Cellular traffic capacity tends to converge with an average as the load on cell site increases, and therefore it is always better to serve with SCPC

This assumption is also common for rural site traffic, especially in peak times. From a satellite perspective, this logic implies that rural sites would be better off with a SCPC-based (or similar) access technology. The rationale is the conversational characteristics of cellular traffic, even in 3G rural. In other words, one should not expect significant statistical gains due to bursty traffic patterns. This is the impact of the constant nature of voice traffic coupled with a small amount of data. However, given that SCPC for every rural site is cost-prohibitive, this does not allow for mass deployment, and thereby does not decrease the digital divide.

To check the claims of the SCPC and MF-TDMA camps, we took a real rural network measurement. This network backhauls and accelerates 40 rural /semi-rural 3G small cells over satellite. Satellite segment is shared between two additional applications – rural schools and rural /semi-rural 2G/3G macro sites. We used Wireshark (a network protocol analyzer) to analyze an hour of a peak time traffic sample. It is important to note that most of the traffic during this hour had similar patterns, as we are about to describe. For the report we randomly selected two minutes around midday. The results below represent overall capacity and the top four most active sites with the following IP addresses suffix: 218, 106, 210, 122, during this two-minute period. Usually people refer to daily, hourly or even quarter-hourly traffic statistics. We tried to drill down and measure at 10-second intervals.

10-second intervals

Even at 10-second granularity, there is very little variance in traffic, both in terms of overall traffic and per-site traffic. However, most important is the ratio between the average and the peak. Unfortunately for the MF-TDMA camp, there was no indication of large gaps between the average and the peak, as depicted in **Error! Reference source not found.**.

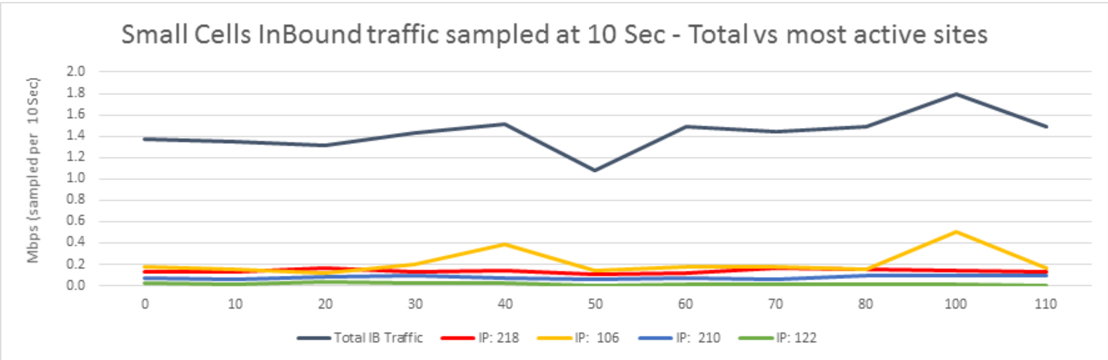


Figure 1: Small Cells Inbound traffic at 10 sec intervals

Conclusion: SCPC advocates might be right… if most sites are consuming around average, the best option in terms of spectral efficiency would be to allocate capacity per site.

However, something in this result just didn't feel right. We decided to investigate further.

2nd round – 0.1 msec intervals

As satellites allocate capacity at 40 msec cycles, we reevaluated the samples again but this time at 0.1 sec intervals. Our theory was that averages were not an adequate measure of performance and traffic patterns of cell sites, especially with rural/semi-rural mobile traffic. We took a detailed view of the traffic – max vs avg. for the total and for the four most active sites. For example, we learned that site ''218' had more packets but delivered less bytes compared to site '106' overall. Another interesting point was the ratio between the average and the peak. It was easy to see a huge variance within a second in individual site traffic and between sites. Avg/Max is > 1:2.5 for the total but more important, each site experiences a greater than 1:10 ratio and for fractions of seconds, rarely more than 0.1 msec duration. A detailed summary appears in the table below.

	Total IB Traffic	IP: 218	IP: 106	IP: 210	IP: 122
Max	3,815,440	1,620,400	2,043,440	877,360	560,960

Avg	1,463,061	140,209	217,472	79,152	16,294

The first insight reached by looking at Figure 2 is that there is constant voice and control protocol traffic noticeable in most sites. Second insight: as expected in packet data networks, there is also an abundance of capacity spikes. Each site experiences a traffic burst, but since we have a large sample (40 sites), these bursts rarely happen concurrently, therefore the network enjoys the scale and the statistical multiplex gain of this behavior.

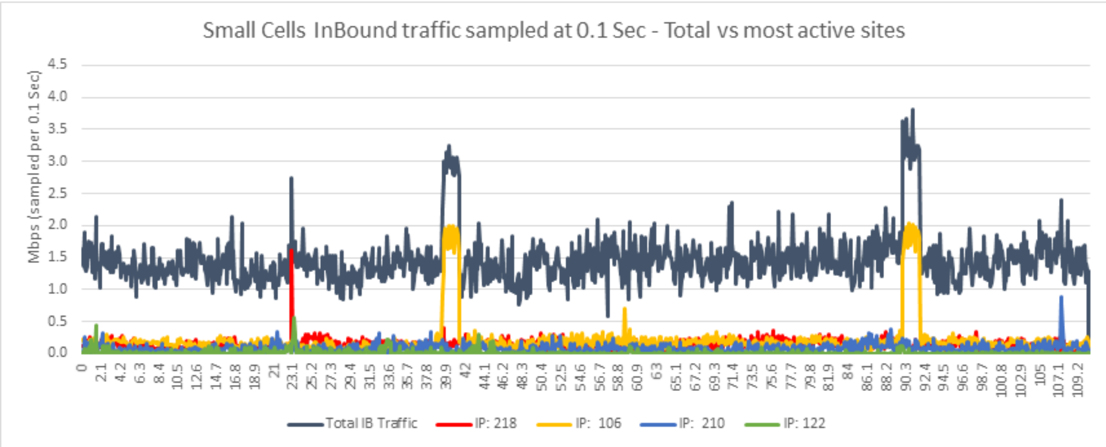


Figure 2: Small Cells Inbound traffic at 0.1 msec intervals

__**Conclusion I:**__ Myth is Busted!

Clearly, this is not the traffic pattern in which you would prefer to use SCPC. On the contrary, this is exactly the type of traffic for which you use MF-TDMA

An additional insight refers to the total capacity as depicted in Figure 2. Total capacity ranges around an average, but there are multiple spikes as well. These traffic bursts are served from the overall capacity of the network, as this is a multi-application network serving also broadband for education and macro cells. The statistical gains are between the macro, small cells and the education applications. Without needing to provision the maximum required capacity, this network design can satisfy the needed quality of experience.

__**Conclusion II:**__ Multi App with shared bandwidth, using an advanced quality of service mechanism and coupled with MF-TDMA, is the preferred path for this rural small cells deployment.

Public Safety Incident Analysis

Incident traffic planning, especially when coupled with public safety, is one of the most demanding applications. For different reasons, it is common to use SCPC in backhaul for public safety sites. But as incident management evolves, this technology approach require re-evaluation. For this paper we used the Incident Analysis (2011) of the "shooter in high school" scenario. This is based on the Minnesota Department of Public Safety analysis[1].

The Myth:

Public safety traffic requires mission-critical voice and data at constant rates, and therefore the only relevant option is to use SCPC.

The scenario described in this case highlights some of the complexities in this environment. The routine traffic of this site is around zero. Public safety use their wireless networks for routine communications. While they do perform emergency drills, the network is built for emergencies and incidents.

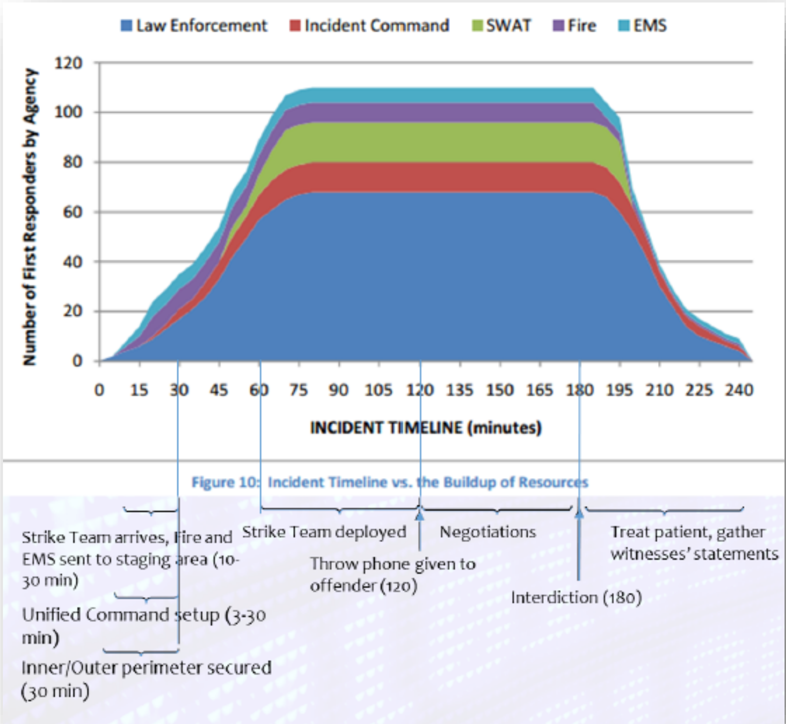


Figure 3: Incident timeline vs. buildup of resources

The interesting part is that within an hour from the beginning of the incident, the site had to serve 110 officers and other first responders. The buildup of forces proceeds at such a rapid pace that emergency response communications deployment is irrelevant. **Error! Reference source not found.** describes the buildup of first responder load at the site. Within four hours the site is almost empty again and everything is back to normal. Even more interesting is the buildup of traffic at the site. Within minutes capacity demand goes from no traffic to maximum site capacity with a distinct change in Downlink (DL)/ Uplink (UL) ratio.

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[1] Source: Minnesota Department of Public Safety and PSCR

https://dps.mn.gov/divisions/ecn/programs/armer/Documents/Minnesota_Needs_Assessment_Report_FINAL.pdf

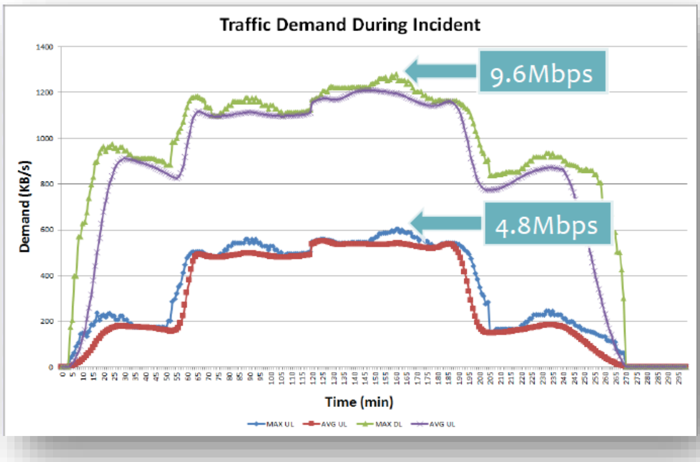

Figure 4: Traffic Demand during Incident

As seen in Figure 4, traffic surges to 9.6 Mbps in the DL and 4.8 Mbps in the UL. Using SCPC for routine traffic makes very little sense as these remote public safety sites are almost idle most of the time. During the incident, there is a need to instantly allocate much more satellite capacity to relevant sites. Shifting to pre-reserved spectrum for high capacity on a dedicated carrier or using a shared spectrum but with higher priority is mainly a budget decision. Other considerations are the backhaul performance envelope required and the relevancy of shared spectrum for additional applications.

Going forward with Public Safety LTE (PS-LTE) deployments, first responder agencies would expect 50 or even 100 Mbps per site during an incident but we all hope these sites would continue with their nearly idle traffic. SCPC-based links are not designed to offer this level of flexibility in network operation. Returning to budget considerations, the goal would be to set up several PS-LTE sites, with a backhaul network that can sustain PS-LTE high level of service, but with a reasonable operation cost for the agency.

Conclusion: Myth is Busted! MF-TDMA is optimal for most of the scenarios. The perfect solution would probably be a mix: MF-TDMA for routine traffic and most incidents with an on-demand switch to SCPC in limited special cases.

Summary

SCPC has many advantages. It is a simple and reliable technology, supported by overall low-cost equipment, and can operate with practically any bandwidth. However, its main disadvantage is the inefficient use of satellite bandwidth with bursty packet data transmission. As for the question of which access scheme is best, there is no clear answer. As always, it depends on the case. At Gilat, we believe you should have both options available and select the optimal technology either per case or even per incident. As a rule of thumb, most cellular backhaul cases are served best with TDM for outbound and MF-TDMA for the inbound. Some are served best by dynamically switching between the two in the inbound. A diminishing minority is still best served by pure SCPC.

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