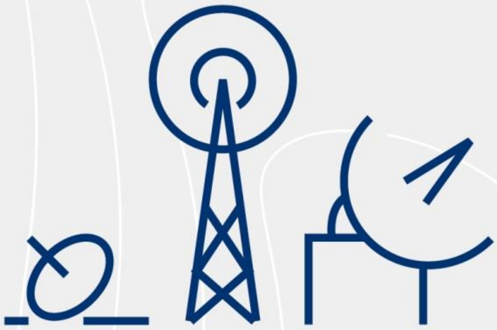
WHITE PAPER



Satellite-Based Cellular Backhaul in the Era of LTE

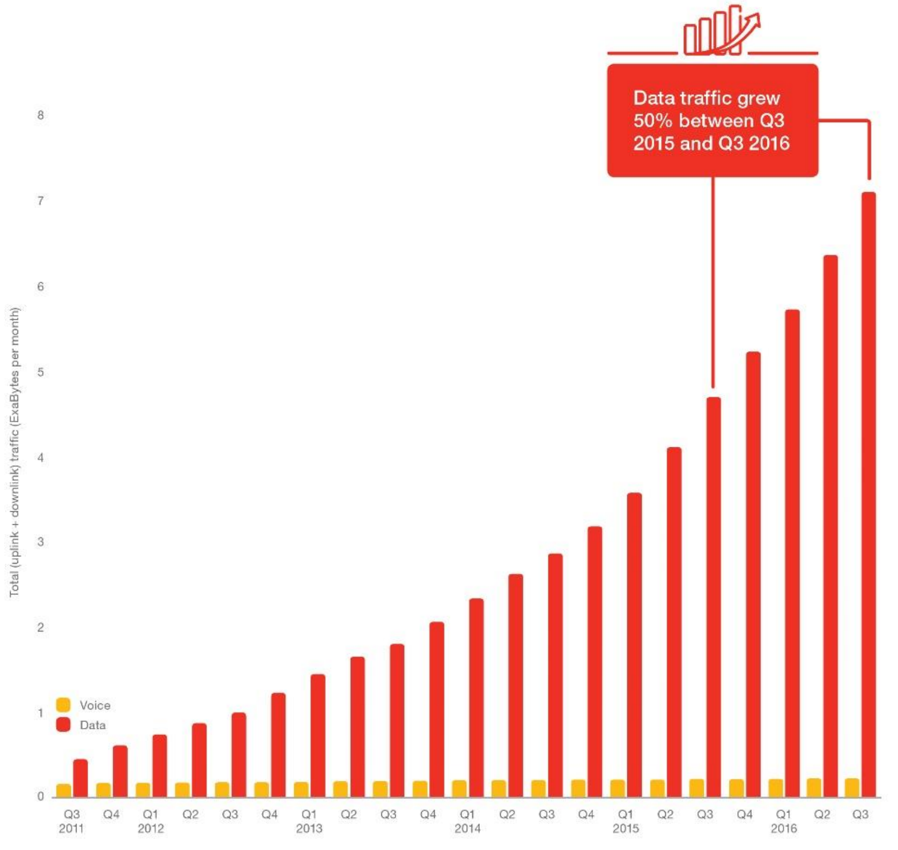
Boundless Communications

Gilat

Introduction

As cellular networks evolved from 2G to 3G/LTE and beyond, the need to provide a cost-effective and high performance satellite backhauling solution has grown.

In the era of 2G, the requirements imposed on satellite-based transmission were quite basic. Virtually all network traffic was based on voice, characterized by symmetric traffic and requiring dedicated links. SCPC (Single Channel Per Carrier) technology was developed in the 1980's, and provides a two-way symmetrical "pipe" similar to a leased line or microwave circuit. SCPC was easy to understand and easy to implement, based on the number of TRX at the BTS. Thus, SCPC solutions are typically employed to support 2G backhaul over satellite.



Source: Ericsson traffic measurements (Q3 2016)

[1] Traffic does not include DVB-H, Wi-Fi, or Mobile WiMAX. VoIP is included in data traffic

However, as 3G and 4G networks enhance and replace 2G, SCPC technology becomes less effective. Non-symmetrical 3G data, and even more so 4G data traffic that varies greatly from average traffic to peak traffic.

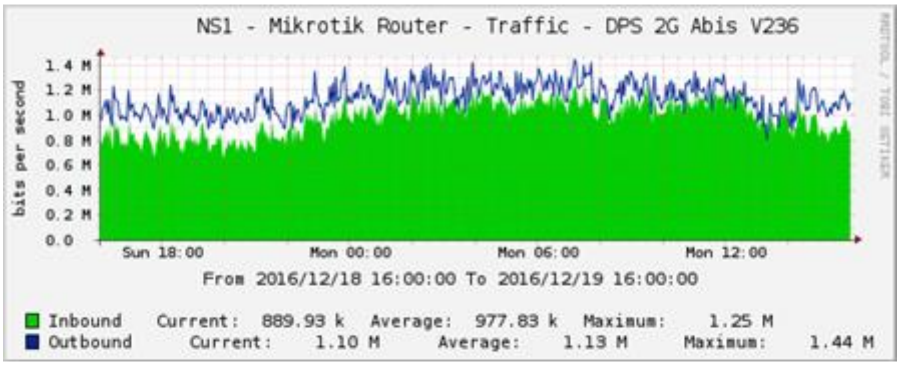
In this scenario, assigning a dedicated SCPC satellite circuit based on peak traffic becomes hugely expensive when implemented for a medium to large network of sites. A Dynamic SCPC mechanism was later introduced in order to support this change in traffic patterns assuming that automatically adapting Dynamic SCPC channels might provide a better solution to the challenge. Unfortunately, Dynamic SCPC is not adaptive enough on its own in today's demanding traffic requirements. A shared bandwidth mechanism, which is very fast to adjust (measured in tens of milliseconds), enables very high peak performance to every single network node. The shared bandwidth mechanism enables to keep a relatively low average performance across the network providing a cost-effective solution for these scenarios. Ultra-fast MF-TDMA "bandwidth-on-demand" technology provides the solution. Over the last decade, many MNOs have replaced their ageing SCPC-based satellite transmission solutions with MF-TDMA solutions, primarily to economically enable rural coverage over satellite as well as to save OPEX cost.

The Emergence of 4G Exacerbates the Situation for Satellite-Based Backhaul

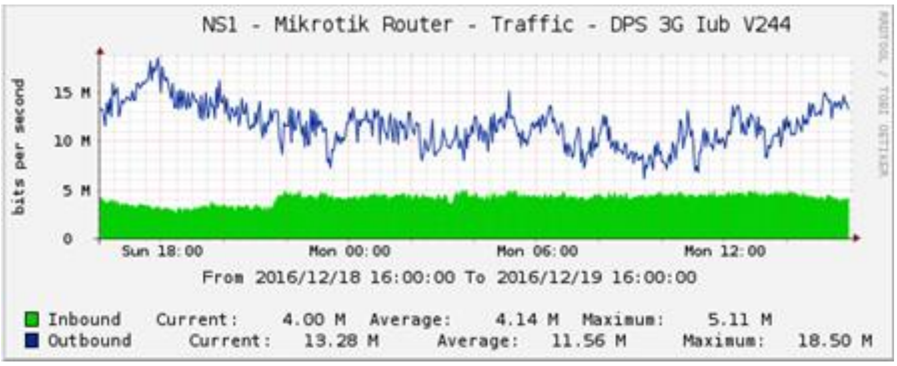
Dramatically increasing data rates above and beyond 3G requirements and the bursty nature of 4G data traffic means that assigning a fixed SCPC or relatively slower adapting Dynamic SCPC satellite circuit to a site based on peak 4G traffic becomes prohibitively expensive. These effects can be clearly viewed in the below real-life example as taken from an operational network.

The diagrams below clearly show the differences between the traffic profiles of a 2G site, a 3G site and a 4G site, as taken over the same period:

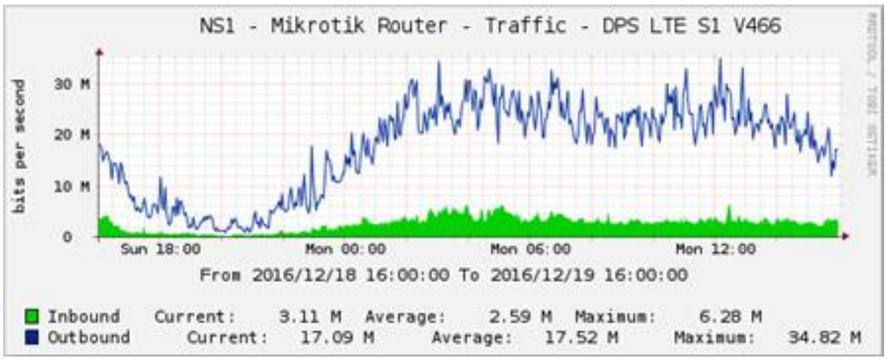
2G
- Low rates 800-1400kbps
- OB/IB Near symmetric (~1:1)
- Small IB peak-to-Average ratio (1.27)



3G
- Higher rates- up to 18/5Mbps
- OB/IB ratio increase to ~3:1
- Small IB Peak-to-Average ratio (similar to 2G)



4G
- Even higher rates- up to 35/6Mbps
- Much more fluctuating traffic pattern
- OB/IB ratio further increased to ~7
- IB Peak-to-Average ratio increased to 2.4!

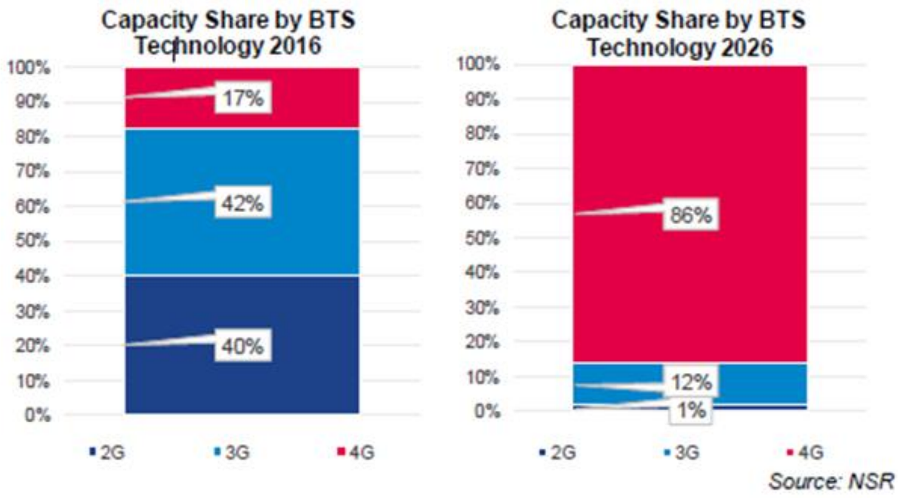


Beyond
Link Speed!

However, link speed and traffic profiles are not the only roadblock to 4G cellular backhaul over satellite. Even if satellite bandwidth was free, the impact of satellite latency on HTTP traffic means that download experience at the user's handset will not exceed ~ 2.5 Mbps even if the satellite link itself operates at 100 Mbps. It's clear that some type of acceleration solution is needed in order to offer reasonable 4G download speeds at the subscriber handset over satellite. Telco's require today additional unique features to support network transparency and security to enable ease of deployment. Maintaining a single network architecture over heterogeneous environments has become a necessity ever since networks have increased in size.

We can assume that the trends that we witness today as data traffic increases significantly will only grow in the future as the technology continues to evolve, and as traffic patterns continue to grow in a substantial way. Together with increased traffic rates, single RAN solutions and assimilation of multiple cellular technologies, issues like high volume of packets per second is also emerging as a challenge. Integrated methods such as packet aggregation for example will be required to handle such high volume of PPS.

See here an example of market predictions for different leading cellular technologies going forward:



Essential Technologies for 3G/LTE Backhauling over Satellite

3G/LTE Backhauling service depends on support for very high throughput all the way to the end user handheld device. Since GEO satellite networks have an inherent 650ms delay, the VSAT platform must be capable to overcome this delay by employing different techniques such as acceleration, BW optimization integrated with Layer-2 networking and end-to-end encryption.

Five key technologies must be available for a successful backhauling over satellite, providing terrestrial-like user experience:

- Speed - Multi-Tiered Integrated acceleration to deliver true-LTE speeds of 150Mbps to handheld devices
- Efficiency - Highly Adaptive & Ultra-fast TDMA access to enable maximum effective use of satellite capacity
- Quality of Service (QoS) - End-to-end QoS to maintain service quality in shared bandwidth networks
- Encryption and Acceleration - Secure encrypted communications required from RAN to gateway
- Layer-2 Support - Network connectivity at the RAN side and point of aggregation for seamless integration with existing MNO's network infrastructure

Gilat's Solution – SkyEdge II-c Capricorn

Since 2015, Gilat has made 3G/LTE backhaul over satellite a reality, with the introduction of the SkyEdge II-c Capricorn, the ultra-fast MF-TDMA VSAT that supports download speeds of 200 Mbps.

This product introduction came after more than a year of evaluation by various tier-1 MNOs providing 4G service. This future-proof fast MF-TDMA VSAT has the ability to bridge between different traffic patterns and provide seamless scalability when traffic requirements grow in a fast and sudden way. MNOs are able to differentiate themselves and to gain an important competitive edge when deploying multiple sites. Installation and deployment can now be implemented for the required bandwidth, and future expansions/needs can be handled without additional equipment investment.

Gilat's Capricorn solution addresses the following challenges which had previously impaired the use of satellite for 3G/4G cellular backhaul:

Speed

SkyEdge II-c implemented the highest multi-tiered acceleration for LTE achieving 150Mbps of TCP traffic to a single handheld device. This unique patented technology enables to deliver maximum user experience to end users over satellite.

It enables acceleration of traffic inside the LTE GTP tunnel and is implemented in the SkyEdge II-c Capricorn family of VSATs. This Super-fast acceleration is deployed already in several tier-1 cellular backhauling networks worldwide.

Note that acceleration technology must be integrated with the QoS in the VSAT and hub to ensure full synchronization between the instantaneous real-time available bit-rate and the end-to-end network traffic demand.

Unlike several 3rd-party solutions that provide external accelerators, Gilat's SkyEdge II-c platform and Capricorn VSATs deliver a single board integrated software and hardware solution delivering acceleration, encryption and QoS.

Without such tight integration, the result will be packet loss and severe service degradation at times of changes to the satellite link (e.g. due to rain or atmospheric affects). Gilat's SkyEdge II-c system has the inherent ability to handle up to 70K PPS and support very high speeds of IPSec traffic using its Capricorn MEC VSAT.

Efficiency

MF-TDMA provides the best solution for 3G and 4G bandwidth utilization.

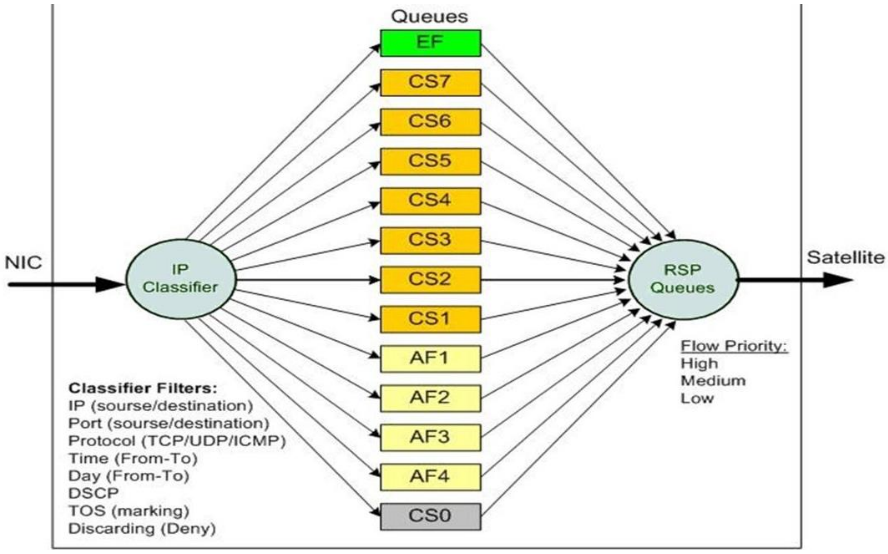
The installed base of SCPC technology for CBH transmission has been rapidly declining over the past decade. Some new "hybrid" solutions claim to employ Dynamic SCPC like carriers that jump, move and adapt based on traffic, but large scale commercial installed base of this technology for Cellular Backhaul transmission is very difficult to be found.

It may appear that a single SCPC or Dynamic SCPC site is more efficient or can offer higher speeds, but if implemented for an entire network of sites, a standalone SCPC or Dynamic SCPC solution will cost much more than an MF-TDMA based solution.
This is the primary reason why the installed base of SCPC solutions for CBH solutions is fading. Moreover, modern state-of-the-art codes nowadays have evolved to a level in which their link performance is close/similar to SCPC link performance.

In special cases when SCPC may still be required, the Gilat Capricorn modem can support Dynamic SCPC links of up to 100 Mbps. Therefore, the network can implement MF-TDMA and use Dynamic SCPC only in the rare cases where it has an advantage.

Qos (Quality of Service)

SkyEdge II-c Enhanced QoS enables granular configuration of QoS priorities with up to 13 different queues. The advanced QoS delivers maximum user experience in shared bandwidth cellular backhauling networks and enable to support combined services of 2G, 3G, LTE including VoLTE at highest call quality.



The QoS mechanisms enables the service provider to prioritize specific traffic class defined by flexible rules to ensure performance and to improve end-user experience.

Encryption & Acceleration

Gilat's Capricorn MEC (Mobile Edge Computing) delivers true LTE speeds over satellite exceeding 150Mbps with support of IPsec directly from remote cell connected to the remote VSAT.

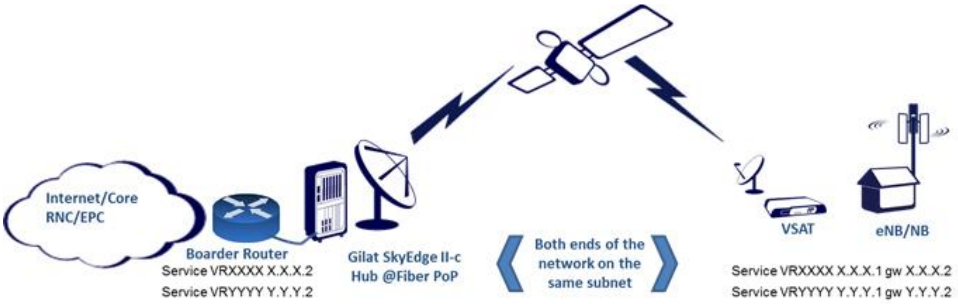
It includes Gilat's patented GTP cellular data acceleration at unprecedented speeds without packet loss under fade conditions.

As with all versions of Capricorn, Gilat's 4G acceleration is embedded, rather than an external 3rd-party solution. External 3rd-party accelerators have been shown to experience packet loss.

Layer-2 Support

In order to support diverse operational deployment scenarios, Gilat's satellite-based solution optionally implements carrier grade Layer 2 support in large-scale networks, this includes the ability to accelerate inside the LTE GTP Tunnel as well as being IP transparent.

Thus, heterogeneous backhaul networks comprised out of terrestrial and satellite technologies can be operated coherently and simply and maintain TCO efficiency.



This unique technology enables seamless operation of standard terrestrial operational practices and satellite networks.

Why Ultra-fast TDMA is the Only Viable Solution

Ultra-fast MF-TDMA VSAT is a must— the expected performance in LTE networks is at least three to four times faster than HSPA+ speeds.

As traffic fluctuations increase significantly in data oriented cellular networks, satellite backhaul must "catch-up" and enable ultra-fast adaptation and network dynamics to support the cellular RAN needs, on top of the network dynamics imposed by the satellite link itself (e.g. fades).

To support all the above in an efficient way, the satellite network must be able to react much faster than the overall network imposed changes, i.e. with a resolution of tens of millisecond.

Any slower response will result in either a waste of BW (when RAN need is reduced quickly) or with un-supplied RAN demand, which may result in dropped packets causing service degradation!

Satellite Backhaul Access Schemes

While considering different access schemes, which are available today such as MF-TDMA, SCPC, Dynamic SCPC and other proprietary hybrid solutions it is clear that we should evaluate several parameters rather than focus on a single one as was done so far in the past.

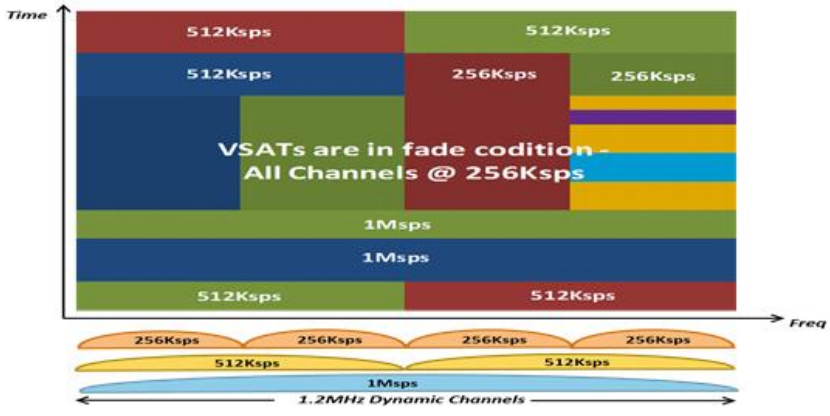
In designing legacy satellite transmission networks, where traffic patterns were primarily based on voice service, the design and solution was based solely on spectral efficiency. The assumed traffic pattern was relatively fixed (i.e. small peak to average ratio) and almost symmetric in nature. In this scenario, the main criteria was how much traffic can the device support in the uplink or downlink while using the smallest amount of space segment possible.

Today, as 3G/4G services are rapidly introduced, traffic patterns have changed significantly and it is far from being fixed or symmetrical as in the past, as seen the examples above.

When considering traffic engineering aspects, one should analyze the traffic in a detailed way to fully grasp the change that has occurred over time. When the traffic pattern is variable and the difference between peak demands in a particular cell varies greatly from the average, it is prohibitively expensive to use a dedicated link or a slow adaptive link (=>1Second).

In this situation, sharing the satellite bandwidth resource among multiple cells is much more cost-effective. Networks operating in highly adaptive TDMA mode take advantage of the dynamic nature of the traffic and statistically multiplex between cell sites. These networks allow bandwidth resource sharing, which can offer service providers reduced operating expenditures (OPEX) advantages.

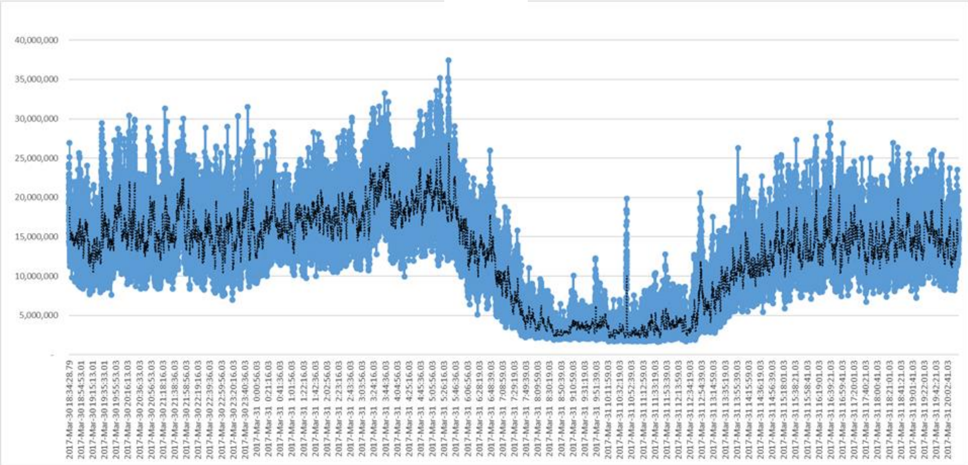
Gilat SkyEdge II-c platform fast adaptive TDMA manages mili-second allocations (calculated and adapted 25 times a second) in order to to accurately follow traffic patterns to provide the best performance and at the same time deliver maximum fill ratio and thereby actual network-wide space segment efficiency.

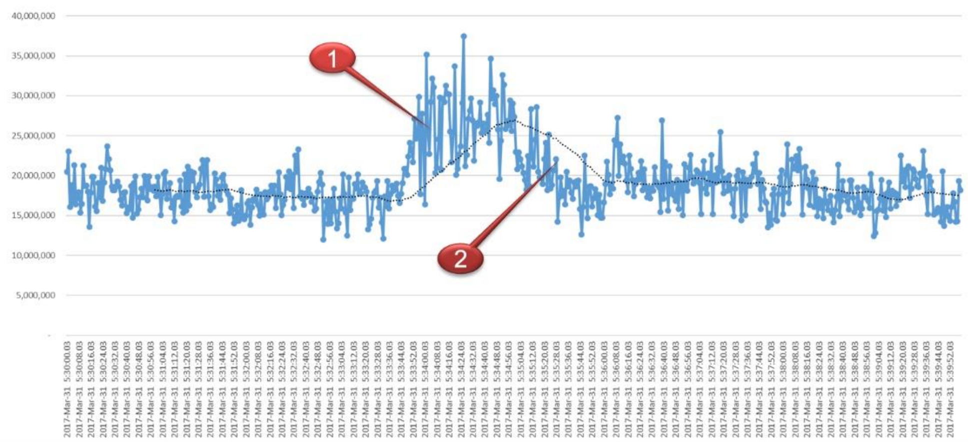


Slow adaptive TDMA platforms cannot deliver high fill ratio and hence will deliver less bit/Hz when deployed for large networks.

Real Life Traffic Analysis Trends

The following traffic pattern was taken from a live 3G site carrying voice and data, over a period of 24h:



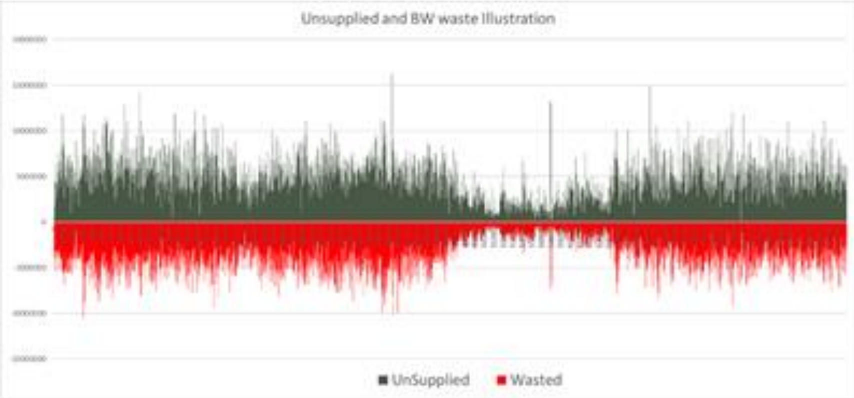


Blue line – shows the actual traffic profile of the site (over satellite backhaul), as measured with high resolution sampling.
Black line – shows a simulation of traffic profile of slow resource allocation by applying 60 samples moving average to the actual measured data.

From the diagram above we can clearly see the effect of slow resource allocation as it is reflected by the difference between the blue and the black line:
When traffic sharply increases (1) – a slow resource allocation (the black line) can't response quickly enough and provide the required bandwidth, hence most probably will cause packet drops.

When traffic sharply drops (2) – the slow resource allocation can't release the resources fast enough hence resulting in a bandwidth waste.

Looking at the above across the 24h sampling interval, we get the following result:



Grey line – represent unsupplied demand (when Blue>Black)
Red line – represents wasted BW (when Blue <Black)

Hence – slow resource allocation brings the network to be always either wasting BW or un-suppling the RAN needs!

Summary

Achieving superb user experience while cost-effectively supporting the ever growing and highly dynamic needs of a 3G/4G cellular backhaul networks requires a suite of capabilities to ensure that the proper resources will be provided, on time and with high efficiency over the satellite links.

- Speed - Multi-tiered Integrated acceleration to deliver true-LTE speeds of **150Mbps** to handheld devices
- Efficiency - **Highly Adaptive & Ultra-fast TDMA** access to enable maximum effective use of satellite capacity
- Quality of Service (QoS) **- End-to-end QoS** to maintain service quality in shared bandwidth networks
- Encryption and Acceleration - Secure **encrypted** communications required from RAN to gateway
- Layer-2 Support - Network connectivity at the RAN side and point of aggregation for **seamless integration** with existing MNO's network infrastructure

Gilat SkyEdge II-c system was designed to supply all of the above and it is currently the only field proven system, successfully deployed by multiple tier-1 mobile network operators across the globe.

Gilat Satellite Networks

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