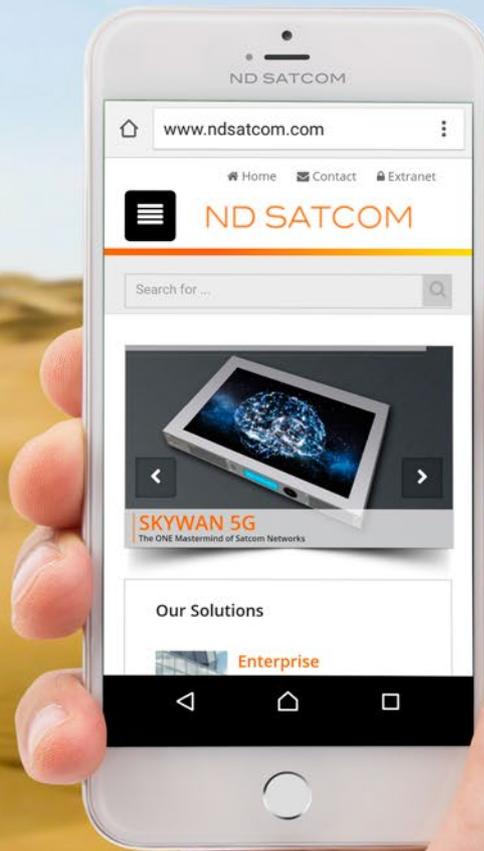


ND SATCOM

Cellular Backhauling over Satellite:
The Smart Way To Do It



EXECUTIVE SUMMARY

Satellite operators have been working with mobile operators for many years now. For the former, it has been a lucrative business with highly desired customers; for the latter, it has been the option chosen last. When compared to mobile's own transmission networks based on high-throughput, low-cost optical networks, satellite has been characterized as an expensive, delay-introducing medium with limited throughput, to be used only when necessary. If satellite operators want to expand their business with mobile operators, they will have to move on from their decades-old paradigms and start learning and providing what mobile operators really need. These include: all the benefits of statistical multiplexing without limitations on inbound routes, number of stations per channel, number of channels a station can use, QoS functionalities in-line with what they already use in their networks, flexibility in topology allowing changes at any time, and an efficient pay as you grow solution without large upfront investment and unused capacity. ND SatCom's SKYWAN 5G solution offers all that and more, while simultaneously providing space (fits into one rack unit) and cost savings.

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1. INTRODUCTION

While mobile penetration in some developed countries has stabilized at around 120% of the population for some years now, there are still around 3 billion people without access to mobile telecommunications, which is almost 40% of the world’s population.¹ Global mobile data traffic overtook mobile voice in December 2009; only a year later the volume of mobile data was twice that of mobile voice.² Mobile operators have been very efficient in building the infrastructure and providing mobile services to 60% of the world’s population, yet to serve the remainder a new telecommunication paradigm has to be adopted.

The business model behind the swift adoption of mobile services does not fit anymore. Average revenue per user (ARPU) in remote and rural areas cannot cover the cost of telecom equipment needed to provide the service, i.e., base stations and backhauling infrastructure. Operators must lower both CapEx and OpEx in order to run a profitable network in those areas. Moreover, they need to do it fast, because other players in the market are becoming more interested in offering the same services. Those players are, albeit smaller, very flexible and adapt to changes rapidly; plus they are open to new technologies without the need to operate expensive legacy infrastructures.

According to Ericsson³, a great savings potential lies in the network design phase, i.e., *network dimensioning*: “Network measurements reveal that the low-load sites are often over-dimensioned, i.e., operating at sub-optimal capacity utilization levels. This leads to higher energy consumption per transferred byte. Precise dimensioning with the right radio site hardware for each traffic segment can reduce energy consumption by up to 40 percent while maintaining network performance.” What goes for energy in this case also goes for capacity, which is even more pertinent when backhauling is done over satellite. With satellite bandwidth still so expensive, it is clear why operators choose it only when absolutely necessary. It is a sort of paradox: satellite operators’ hardest sales come from their technically most capable customers – mobile operators. It should not be that hard given all the physical requirements for a cost-effective cellular backhaul over satellite are already there; what is needed is some development work and a bit of imagination. With that in mind, the 3 most important aspects of the new telecommunication paradigm could be described as:

1. Use the best technologies
2. Adopt dynamic network planning approaches
3. Develop new business models

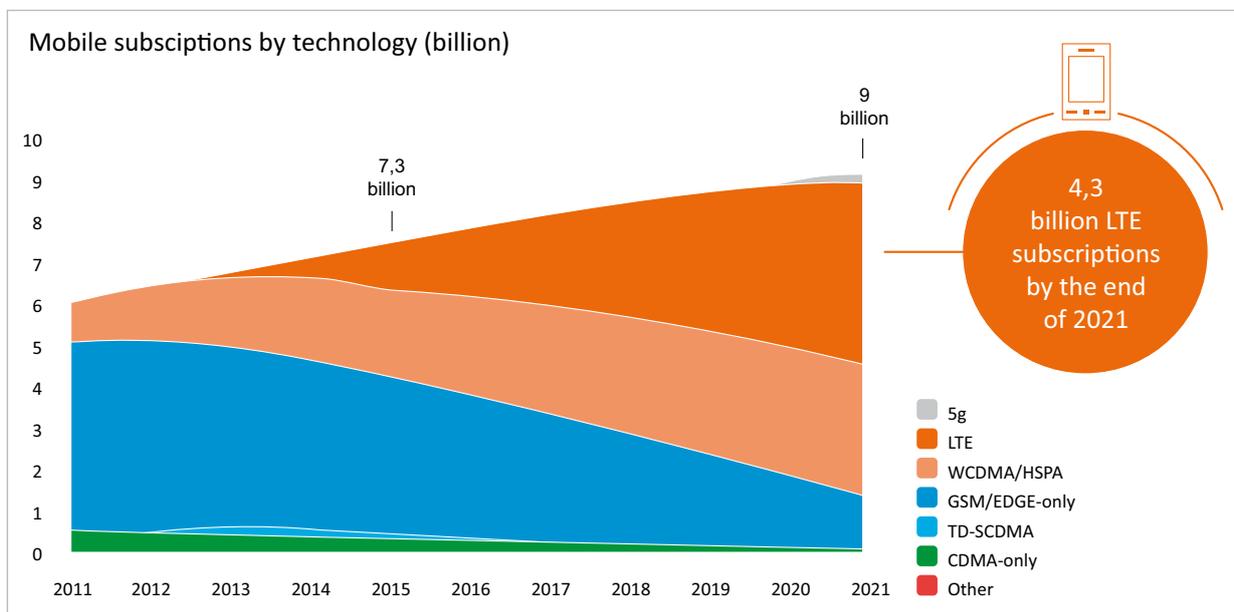


Figure 1: Mobile subscriptions by technology ²

¹ GSMA Global Mobile Economy Report 2016.pdf

² Ericsson Mobility Report, July 2016

³ Ericsson Mobility Report, November 2015

2. USING THE BEST TECHNOLOGIES

Mobile networks throughout developed countries are known for their ubiquity and standardized user experience. As long as the user possesses a standard mobile phone, he can expect to have voice, SMS and data services available wherever he is in the world, thanks to standardized interfaces between the user equipment and the network. This is the case for all major mobile networks available today: GSM, UMTS and LTE. In the case of multi-band phones, a user can use any of those networks depending on his preference or their availability. The user does not have to think about the underlying network infrastructure that serves his communication requests, an infrastructure that can be quite complex and challenging to understand. Figure 2 depicts a typical GSM network architecture.

The network comprises two sub-systems: Base Station Subsystem (BSS) and Network Support Subsystem (NSS). Each node in both sub-systems is full-fledged telecom equipment with redundant power supply, high reliability and protocol stack. They communicate using a set of protocols over standardized interfaces. The most interesting interface from the aspect of transmission planning is the Abis interface between the Base Transceiver Station (BTS) and the Base Station Controller (BSC) because it comes in large quantities and thus contributes to a significant portion of the whole network cost. Connecting the base station (a BTS in the case of a GSM network) to its controller is called mobile backhauling or cellular backhauling.

The number and type of nodes deployed in the network is dependent on many factors and varies from one operator to another. For example, a network of 1 million subscribers could have 1,000 BTSs, 10 BSCs, 5 Mobile Services Switching Centers (MSCs), 1 Gateway MSC (GMSC), and one from each of the remaining nodes (SMSC, SGSN, GGSN, EIR, HLR and AUC). Those remaining nodes are mostly collocated with MSCs and GMSC, and BSCs are usually distributed in regional centers. Operators have a great degree of freedom when choosing where to place those regional centers, yet they are usually in bigger cities where it is easy to connect them to electricity and transmission networks and it is convenient for employees to come to offices. Nodes are connected together either locally with cables or by some kind of transmission network that operates between the locations. This could be Leased Lines, PDH, SDH, Frame Relay, ATM, Ethernet, IP, MPLS, Microwave, Satellite or something else. The transmission network can be operated either by the operator or be leased from another or incumbent operator. In both cases the use of a transmission network costs a significant amount of money. When choosing where to place BTSs, more limiting factors come into play. Operators want to cover as many customers as possible with their signal and often they are bound by their concessions to cover a specific territory span as well. Sometimes they have to place their BTSs in places which are far from ideal in terms of infrastructure availability. This is where the art of cellular backhauling comes into play.

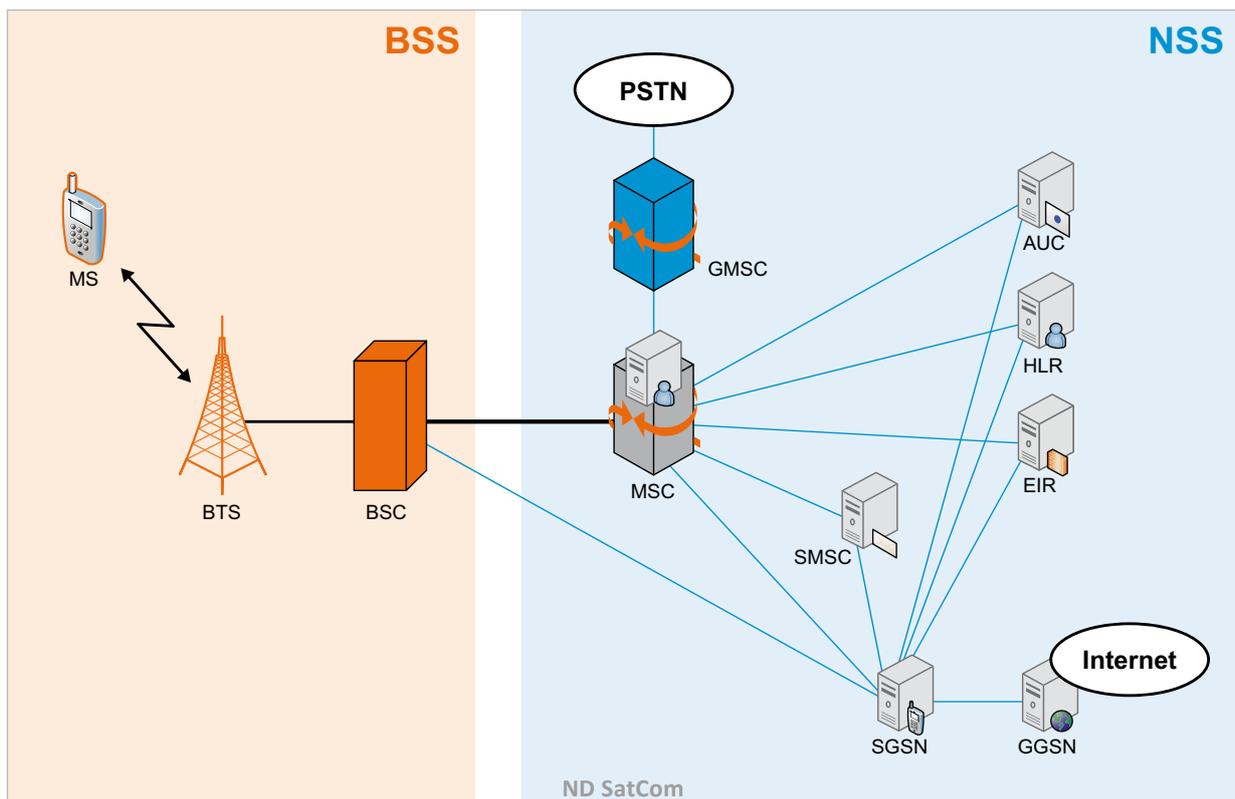


Figure 2: GSM network architecture

SATELLITE AS A BACKHAUL

From the early days of NMT, through GSM and UMTS, to fast LTE networks throughout the world today, various technologies have been proposed, adopted or rejected during decades of rigorous live testing. FDMA, TDMA, CDMA and all their variations and mixtures were tested to find the most efficient way to transmit data, not only on the air interface, but also on backhauling networks, whether access, distribution or core, via cable, fiber optics or radio. Each of those technologies was placed in a network segment where it could be most beneficial, and each of them came with a myriad of proponents who tried to push them even further. While those camps can be hard to reconcile, most agree that those networks must be efficient in handling the dynamic nature of user traffic. It is almost impossible to find an engineer now who would argue that static, circuit-switched technology is best suited to serve the bursty networks of today, even in the oldest system halls of an incumbent operator far away.

However, with the satellite industry struggling hard to become the new best friend of mobile operators worldwide, some parts of that industry are sending out the wrong message. Mobile operators are still annoyed by the decade-old noise coming from their circuit-switched counterparts who call their technology SCPC and try to convince that it is dynamic. This not only makes it harder for manufacturers of highly efficient modems to sell their products to mobile operators, but also casts a shadow of ignorance on the satellite industry as a whole. Mobile operators have forged their way to operating the most efficient networks the world has ever seen; they have seen it all and tested it all.

They have experts who have dealt with everything from Leased Lines to X.25, Frame Relay, PDH, SDH, CWDM, DWDM, ATM, Ethernet, IP, MPLS, all kinds of Pseudo wires, cross connects, multiplexers, circuit switched, packet switched, routed, labelled,... and the list goes on. They know exactly what is efficient in which environment and what is not. From their perspective, the use of satellite capacities for their services has the disadvantages of being too slow and expensive and having too much delay. They choose it when they have no other option. This mindset is affirmed when they hear people from the satellite industry glorifying SCPC links, links that are reserved for their full capacity and have to be paid for regardless of actual usage, as being dynamic and suitable to support mobile services. They lose confidence in the satellite industry's reasoning capabilities. Such stand-alone links are just not efficient, even if you call them dynamic, demand assigned or something else. Thus, the satellite industry is seen as being incapable of properly using the number one resource it has at its disposal – the freedom to roam the earth and establish connectivity from any place, wherever that may be. The two technologies mobile operators use do not provide this freedom: 1) cable – because they have to be within reach of infrastructure or close to it to justify laying additional lines, and 2) microwave – because they have to be in the line of sight with the next tower and within an approximately 100 km (62 miles) radius. VSAT networks do not have those limitations; they can share a common bandwidth pool across all connections, wherever they are. The satellite industry has an enormous opportunity to transform its reputation and parlay its competitive advantage.

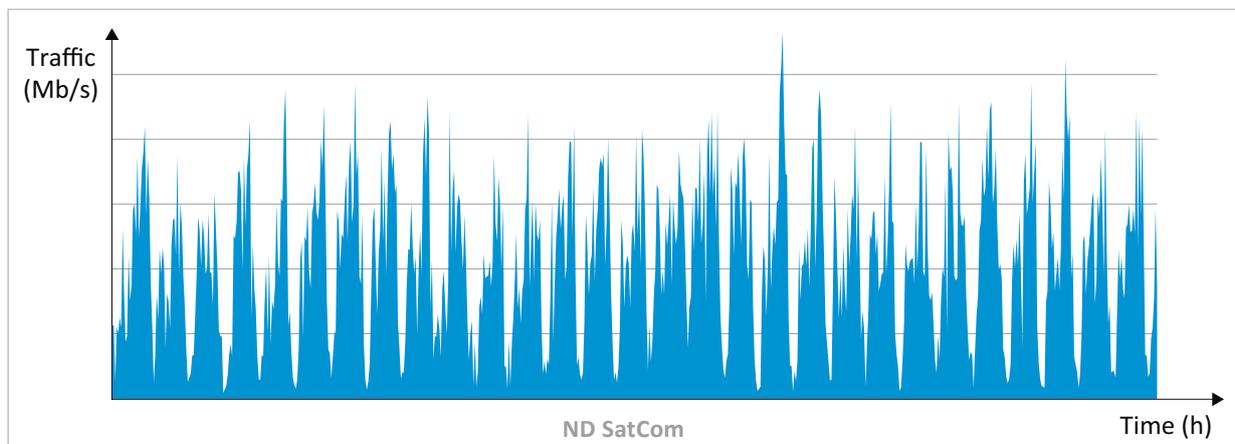
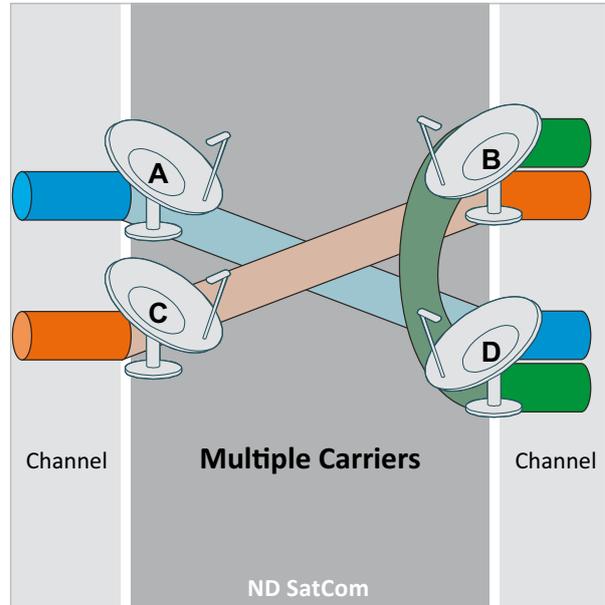


Figure 3: Bursty nature of cellular traffic

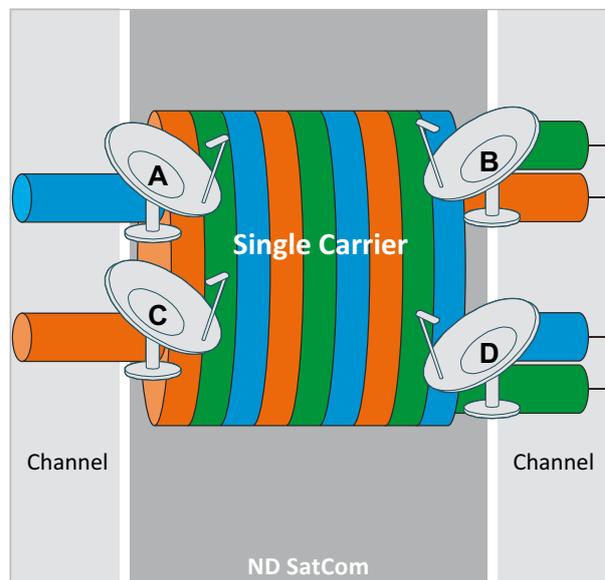
3. ADOPTING DYNAMIC NETWORK PLANNING APPROACHES

The multiplexing mobile operators do on earth should also be done in space. Unlike their terrestrial backhauling networks bound by cable and microwave hop limitations, mobile operators are free to multiplex frequencies, codes and time on their air interfaces. And they do so abundantly. That is the exact same thing VSAT networks should do in space. The Multi Frequency Time Division Multiple Access (MF-TDMA) technology implemented in SKYWAN modems took the best practice learnings on the ground and implemented them to satellites. Today, it is the most efficient way to transport data over satellite when more than two stations are involved. Some of the SCPC vendors have also realized this but, instead of adopting the technology to its full potential, they have decided to put just a DVB-S2 forward channel from hub to remotes, while keeping the return channel in the same old SCPC circuitry. With this halfway approach they are trying to mislead the customer that they, too, have statistical multiplexing just like MF-TDMA modems. As a result the operator gets a somewhat more efficient forward channel than pure SCPC, but loses that gain in the return channel that remained static. In the best case the return channel can adapt to traffic requirements in several seconds, but not in milliseconds as with a real MF-TDMA system. Figure 4 shows the principal difference between SCPC and MF-TDMA forward and return channels.

With such architecture, it is easy to see that for every connection in an SCPC network an additional modem pair is needed: one at the hub and one at the remote. This is true for star topology. Mesh topology does not make sense with SCPC modems given the cost of separate pairs of modems for each direction, making this financially unviable. Figure 5 shows the modem count for SCPC and MF-TDMA star networks.

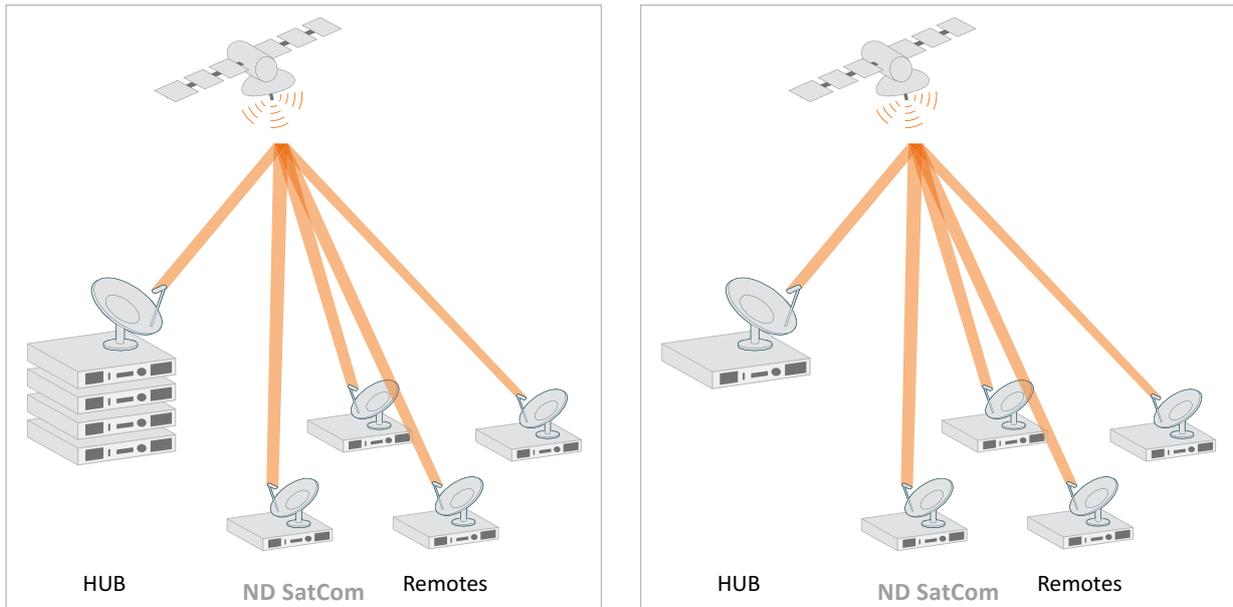


SCPC: Every hop requires a separate channel



MF-TDMA: multiple sites share the same channel

Figure 4: Forward and return channels in SCPC vs. MF-TDMA



SCPC: each connection requires a separate modem

MF-TDMA: one modem for all connections

Figure 5: Modem count in star topology when using SCPC and MF-TDMA

All the benefits of using a SKYWAN MF-TDMA system come from the fact that technology was modelled for user services, not the other way around. Each channel in a network is shared by many sites in a timely manner; statistics show that not all the stations will need the same amount of capacity at the same time. With field-tested formulas, we can calculate how much of the bandwidth needs to be reserved per channel in order to serve all the stations with a guaranteed grade of service. In order to ensure that the most important services always receive the amount of throughput they need, state-of-the-art quality of service mechanisms must be implemented. When high priority services need less throughput, that throughput can be used by best effort services. This is the basic principle ISPs use to grant internet access. Figure 6 shows the actual vs. reserved bandwidth setup done by SCPC, and a statistically multiplexed shared channel of MF-TDMA.

That is what the second part of the MF-TDMA acronym brings. The Multi Frequency part brings additional benefits. Because many frequencies are available, a network engineer can design the network in such a manner that similar sites are grouped together. The criteria for determining the similarity can be different; it can be throughput requirements, rain zone, available antennas or BUCs, footprint coverage, etc. That way, a network can be optimized with just the right sized carriers on one side, and the smallest possible antennas and BUCs on the other side. Thanks to the fast frequency-hopping capability built into every SKYWAN modem, each site can use any frequency for sending traffic and it is all fully automatic without any user effort. Not a single slot is wasted nor sent out partially filled; each channel can be used to its full capacity. Due to the most flexible utilization of all existing carriers, SKYWAN creates a large bandwidth pool shared amongst all participants, not just within one in-route but in the whole network. Combined with the most efficient container-filling mechanisms, SKYWAN achieves the highest efficiency of end-to-end throughput. The synergistic result of pairing the smart and highly dynamic bandwidth allocation with state-of-the-art routing functions, whereby intelligence is built into each modem to avoid single point of failure, is that SKYWAN outperforms even the latest technological innovations that combine TDM outbound with SCPC and limited TDMA return carriers controlled by external intelligence.

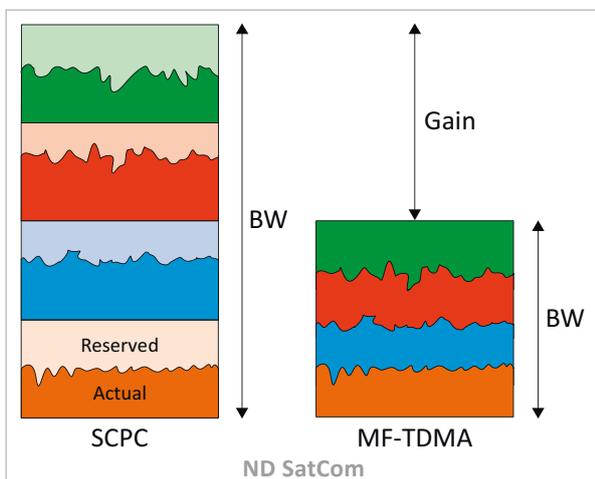


Figure 6: Leased bandwidth with SCPC vs. MF-TDMA

SMALL CELLS AND OTHER EMERGING CONCEPTS

Mobile networks have penetrated our society to an extent unimaginable 10 years ago, and in some areas, even more so than mobile operators had wanted. Along with customer penetration has come technology penetration. Smaller players have entered the market, ranging from school campuses to municipalities, oil rigs to resorts, and all have successfully realized their own networks based on GSM, UMTS or LTE technologies independently of telcoms in their countries. They have shown that it does not have to be as expensive and proprietary as when big telecom vendors build it. A plethora of solutions have been and is available for a fraction of the price that big vendors charge and these solutions are fully interoperable with all the relevant standards. Another active group has been the open source community. From the early attempts of Open BTS, more advanced technologies are now being supported on software-defined radios (SDR) and full protocol stacks, ready to serve any customer with a standard mobile phone. Concepts that originated in the open source community often end up creating whole new ecosystems that support new and more flexible solutions, from which new lines of start-ups emerge to bring them to market. New technologies have been also coming from defense and governmental markets. They tend to quickly find their place in operator and enterprise networks because of the benefits they bring. Such was the case with SDR and satellite networks capable of full mesh topology.

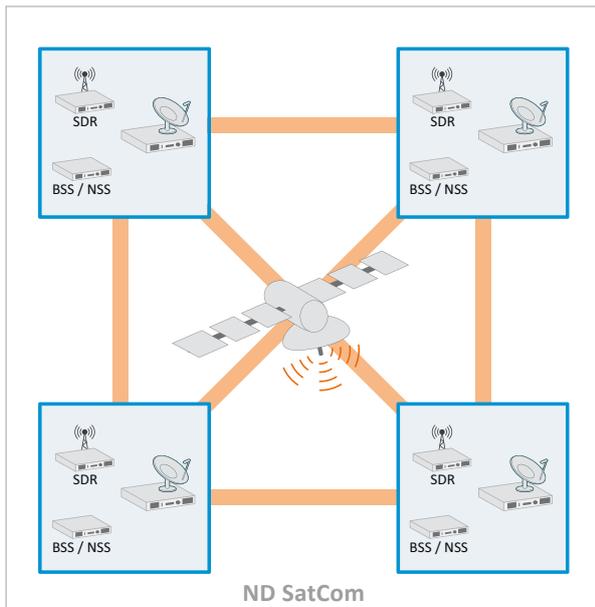


Figure 7: ND SatCom's Full Mesh Open BTS solution on an SDR.

A core network, a sizeable portion of 2-meter racks in a system room to which only a few had access, can now be implemented on a Commercial Off The Shelf (COTS) computer running Linux directly into a satellite modem or base station. This is in line with many initiatives from the mobile industry itself, which is to switch the call or service as close as possible to its source, known as Local Cell Local Switch specification (LCLS, 3GPP 23.284). As a consequence, the network planning process has changed dramatically; it has become far more dynamic than it was ten years ago.

FULL MESH – TOPOLOGY OF CHOICE FOR CURRENT AND FUTURE COMMUNICATIONS

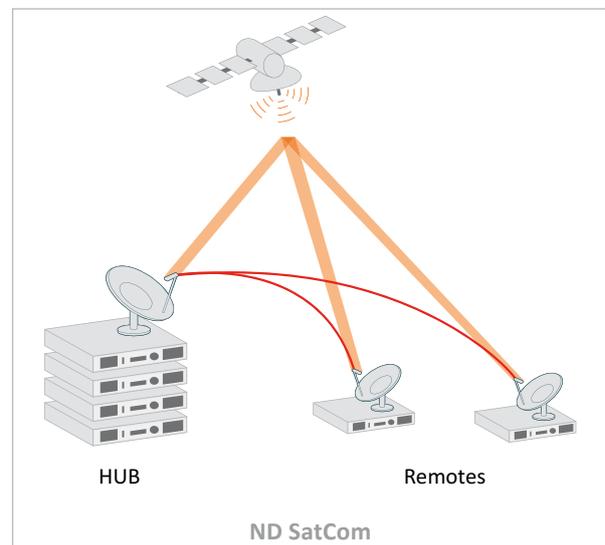
Theoretically, every satellite modem could be capable of upgrading with software switching functionalities. It could then switch the call locally if users were on the same base station. However, what would happen if users were on different base stations? That would require routing the call, along with all the signaling, to a central location via first hop and from there to another remote via second hop. Two satellite hops would not be acceptable because the delay would be too long for a quality conversation. If the satellite modem is capable of full mesh connectivity (there are no physical limitations as already noted), then the switching should occur directly from one remote to the other via single hop transmission. SKYWAN is capable of supporting such scenarios with its native full mesh topology, while both SCPC and legacy TDMA hub-based systems fail in this regard.

Legacy mobile operators are also enjoying the benefits of using full mesh satellite communications. Ever since GSM, many operators have faced big challenges with numerous hours of manual work during seasonal user migrations. What one network looks like in winter might be completely different when it comes to summer, when up to 80% of network resources can be switched to areas where millions of roamers are headed, e.g., the coastline. To prepare for that, a strenuous and error-prone process of switching hundreds or thousands of base stations to a different BSC/MSC must take place, only to put everything back in a couple of months. This is often done by manually patching E1 cables on Digital Distribution Frame (DDF). That is not the case if satellite modems supporting those stations are capable of mesh topology; a simple IP address change is needed to redirect the base station to its new destination. This saves money and time, ensures an error-free migration and keeps things simple.

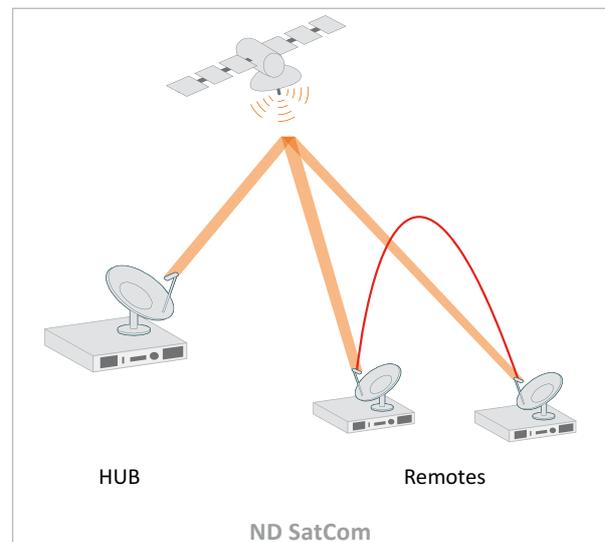
Another example can be found in LTE, where operators support the idea behind MME/S-GW Pooling (3GPP TS 32.752), but lack the technical means to make it financially viable. MME/S-GW Pooling provides network redundancy and traffic load sharing. eNodeB is allowed to connect to more than one MME/S-GW. That way the operator can increase the overall network availability. In practice, geographical redundancy of MME/S-GW nodes is desired and highly recommended. With SKYWAN 5G, every eNodeB can be connected to a number of MME/S-

GW nodes, regardless of where they are, thus enabling the full pooling functionality as envisioned in the 3GPP standard.

With a surge of smart technologies gaining momentum by the day, satellite transmission systems with intelligent features such as full mesh topology are expected to become even more important than today. A growing trend is already bringing those features, previously a privilege of specific customers such as defense or air traffic control, to the mass communication markets of enterprise, operators and service providers.



SCPC: switching via 2 satellite hops



SKYWAN: direct switching via 1 satellite hop

Figure 8: Direct switching via MF-TDMA single hop transmission

4. DEVELOPING NEW BUSINESS MODELS

A paradigm shift in one industry is often caused by developments in another. This is what happened in the mobile industry. Recent technology shifts from governmental and open source communities enabled small companies and organizations to build their own mobile networks based on software-defined radios and software-defined networking, fully independent from mobile operators and big telecom vendors. Mobile operators were left with only two choices; to stand aside and watch them take an ever-growing share of revenues, or to embrace the new approach in situations where it makes sense. The awareness of this new approach is starting to gain momentum simply because the business case figures are clear and positive. The success comes from the fact that only the most efficient technologies were used to build it, and the satellite subsystem to support it should be nothing short of the same – the most efficient, flexible and reliable there is.

On the satellite side, the times are over when only a handful of big players with enough cash to build big teleports were operating satellite networks. Nowadays nobody wants to see an over-dimensioned network, nor a hub for that matter. Traffic is not static anymore, nor should the network be. Dimensioning stand-alone links to their peak rates to see them half empty 90% of the time is just not good enough anymore. Return channels should be just as efficient as the forward channel because that is what user traffic analysis shows.

Only a fully dynamic, efficient network designed to carry bursty user traffic by means of statistical multiplexing can get the job done, as seen so many times before.

A network that can change its topology when required is the only network that will not cause additional unplanned expense when such situations occur.

Customers do not want to experience two hops to get from A to B anymore, especially when the only reason is the decades-old mantra: *We were always doing it like that.*

To best illustrate the financial benefits of using a SKYWAN 5G solution over an SCPC or traditional hub-based solution, two real life examples will be briefly discussed.

CASE STUDY 1: 33 REMOTES UMTS NETWORK

A customer in Asia needed a solution to connect 33 UMTS base stations to RNC. The customer-defined requirements were minimum throughput for each base station of 2 Mb/s and maximum of 6 Mb/s, with less than 10ms jitter. The client provided historic data for throughput figures in other similar network segments. Because of the time distribution of traffic, the data revealed enough space existed to use a statistical multiplexing factor of 2 or 3. For the initial rollout, the more conservative factor of 2 was chosen, which could easily be changed to 3 in future. Those inputs are summarized in the following table:

	SCPC	SKYWAN 5G
Note of sites	33	33
CIR of sites	6	2
MIR of sites	6	6
Multiplexing factor	0	2
Satellite data rate [Mb/s]	198	99
Satellite bandwidth [MHz]	68,55	47,64
Monthly OpEx [US\$]	205.655,15	142.924,79
Monthly savings [US\$]	0	62.730,36
Monthly savings [%]	0	31
Remote modems	33	33
Modems at the hub	33	4
CapEx [US\$]	330.000,00	138.100,00
CapEx savings [US\$]	0	191.900,00
CapEx savings [%]	0	58

Table 1: SCPC vs. MF-TDMA 33 remotes UMTS network

The table shows that, even with a conservative multiplexing factor of 2, the initial investment cost was almost 60% lower with the SKYWAN solution, which sums to \$192k USD CapEx savings. At the same time, monthly operating expenses for the SKYWAN solution was 31% lower than with SCPC. With less than 4ms measured jitter, SKYWAN 5G was perfectly suited for the project.

CASE STUDY 2: 4 REMOTES UMTS NETWORK

This case study describes a legacy hub-based solution vs. a SKYWAN 5G solution. A customer in South America wanted to build a *pay as you grow* network in order to start implementing UMTS NodeBs in remote areas and develop expertise as the network grew. For the initial rollout, a cluster of 4 NodeBs was planned, with the possibility to extend the network up to one hundred. The customer did not want to invest a lot in a hub that would stay empty for a year or two, but wanted to build a flexible network that would support his needs optimally. Comparison figures are specified in Table 2.

	SCPC	SKYWAN 5G
Note of sites	4	4
CIR of sites	6	2
MIR of sites	6	6
Multiplexing factor	0	2
Satellite data rate [Mb/s]	24	12
Satellite bandwidth [MHz]	14,39	11,61
Monthly OpEx [US\$]	43.170,00	34.830,00
Monthly savings [US\$]	0	8.340,00
Monthly savings [%]	0	19.3
Remote modems	4	4
Modems at the hub	1	1
CapEx [US\$]	104.00,00	27.700,00
CapEx savings [US\$]	0	76.300,00
CapEx savings [%]	0	73.3

Table 2: Legacy hub vs. SKYWAN 5G 4 remotes UMTS network

While the SKYWAN 5G network reduced monthly operating expenses by 19% compared to the legacy hub, it also significantly reduced the initial investment cost by 73% because in SKYWAN networks any modem can be a hub and no extra expensive hardware is needed.

5. CONCLUSION

This paper explained basic differentiators between SCPC, legacy hub, and a SKYWAN network. When compared to SCPC networks, the SKYWAN 5G networks perform better in any network with more than 2 stations because in SKYWAN all stations share one common bandwidth pool for both forward and return channels. Thus, a base station may dynamically use from 0 to 100% of a carrier, not only a predefined and limited SCPC connection. With 16APSK modulation available in both forward and return channels, SKYWAN 5G offers enough throughput for any kind of symmetrical or asymmetrical traffic.

Compared to a legacy hub solution, where one big and expensive hub needs to be deployed first in order to start connecting remotes, the SKYWAN network offers a true *pay as you grow* model, where the hub is built with a single, 1-rack unit modem that can be extended later if needed. Additionally, an overlay DVB-S2 signal can be provisioned from the hub to support even higher data rates.

Compared to both SCPC and a legacy hub, SKYWAN offers unique flexibility: there is the possibility to build any kind of topology - from star, multi star, hybrid to full mesh - and to change it anytime. This clear advantage provides additional savings and flexibility to mobile operators, and particularly for advanced and emerging approaches such as Small Cell, Open BTS, and LCLS. Without mesh topology, those concepts lose much of their benefits or become completely unprofitable.

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ABOUT THE AUTHOR



Robert Novak has been involved in cellular backhauling since late 2000, when he joined the operation and maintenance team for transmission networks of Mobilkom Austria Group. He then proceeded to transmission planning for access, distribution and core network in Croatia, as well as for international transmission networks for Telekom Austria Group. Later he accepted the role of Network Product Manager for Huawei Technologies where he focused on transmission networks and backhauling of GSM, UMTS and LTE networks. He presented case studies at various telecom conferences around Europe and conducted a number of Network Solutions workshops for key customers.

Robert is experienced with most technologies used for backhauling to date: PDH, SDH, ATM, Microwave, CWDM, DWDM, Ethernet, IP, MPLS, and Pseudo wires. Since April 2015 his main focus is cellular backhauling over satellite for ND SatCom.

ABOUT THE COMPANY

With over three decades of experience, ND SatCom is the premier supplier of and integrator for innovative satellite communication equipment systems and solutions to support customers with critical operations anywhere in the world. Customers in more than 130 countries have chosen ND SatCom as a trusted and reliable source of high-quality and secure turnkey and custom system-engineered communication solutions. The company's products and solutions are used in more than 200 transnational networks in government, military, telecom and broadcast environments.

ND SatCom's flagship product, the SKYWAN platform, enables international users to communicate securely, effectively and quickly over satellite.

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