White Paper:

A Review of the Two Primary Types of Ka Satellite Systems

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Abstract

The roll-out of Ka-satellites has transitioned from concept to reality, with several systems now in operation and more in the pipeline. Two primary types of systems are emerging: those designed to serve asymmetric broadband applications typified by consumer and corporate internet access, and those designed to serve applications requiring predictable, assured throughput. The key question facing potential adopters of these new systems is which system they should choose for their application. This paper compares and contrasts these two styles of system and provides potential users – particularly the military user - with insights to the types of application each system is best suited to support.

1. Introduction

Ka and satellite is a long story, lasting now for more than 3 decades with some satellites (Italsat, ACTS, Japan domestic satellites, GBS) pioneering the use of Ka-band in the 80s-90s. Since then, the technology and the users' needs (both for commercial users and government users) have evolved considerably, transitioning from concept/experiments to reality/actual operations. Two main categories of systems have emerged: HTS (High Throughput Satellites) and HiCapS (High Capacity Satellites). This paper reviews these two architectures from a user's point of view.

2. Main Features

2.1. High Throughput Satellites (HTS)

A HTS satellite aims at serving a given fixed area through a high number (several tens) of small beams (usually 0.5° beam width or less, but could go up to about 1°) with an aggregate capacity of a few to several Gbps. They maximise aggregate throughput though re-use of frequencies between spots (using at least 4 frequencies or 'colours'). They are designed to serve the consumer broadband market or similar institutional needs. The majority of HTS systems use bent-pipe architectures and operate in a hub-spoke mode (user-gateway). For illustrative purposes, consider the case of North-America:

- The first generation of HTS (e.g. Wildblue, Spaceway-3), already in orbit, covers the full US land mass area (see Figure 1), and offers an aggregate satellite capacity around 10 Gbps, serving hundreds of thousands of users, with forward links up to 2 Mbps per user at an average cost of 60 USD per month.

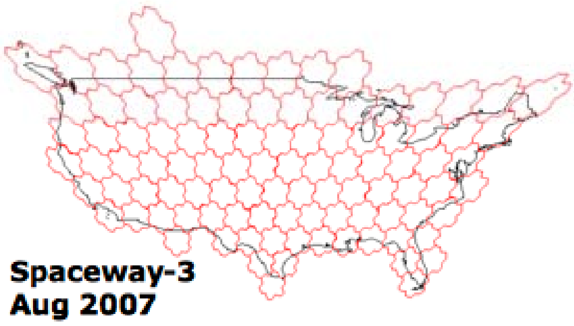

Figure 1: Spaceway-3 coverage [1]

- The next generation of HTS (e.g. Viasat-1) will target areas where demand is highest (see Figure 2) and will offer a satellite capacity close to 100 Gbps (wider bandwidth per spot, improved system efficiency, 4 colours or more, ….), serving several millions of users with forward links up to 8 Mbps per user, with anticipated improvements on prices.

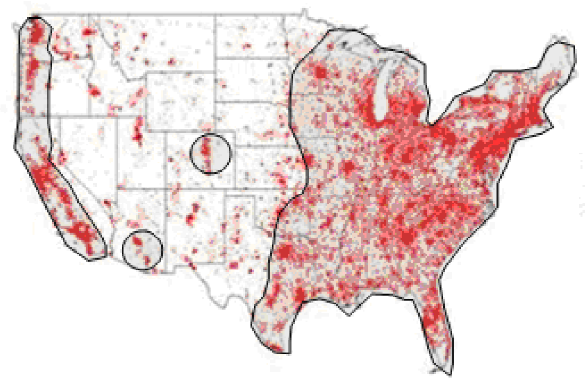

Figure 2: Viasat-1 coverage [1]

2.2. High Capacity Satellites (HiCapS)

A HiCapS satellite usually aims at serving any area of the Earth visible from the satellite through the use of several (typically from 4 to 10) steerable beams (beam width from about 4° down to about 1° – see Figure 3) and with the ability to focus capacity over selected areas (e.g. by overlapping spots or by re-assigning capacity). They can use onboard-processing or bent-pipe architectures and may include some forms of resilience (e.g. anti-jamming capabilities).

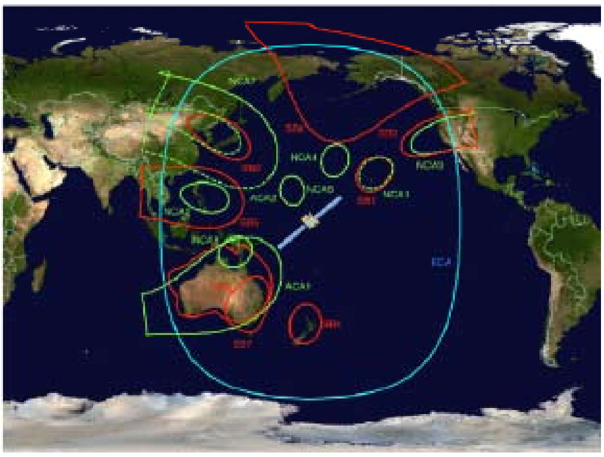

Figure 3: WGS-6 possible coverage (green = Ka) [2]

HiCapS can operate in a hub-spoke mode (a.k.a. 'reach-back', or 'theatre-anchor' configuration) or in a local mode (a.k.a. 'loop-back', 'user-theatre anchor' or 'user-user' configurations). They can support a large variety of fixed and mobile terminals (manned aircraft, UAV, ships, armoured vehicles, …), with antennas ranging from a few decimetres to several meters, and operating with bit rates from a few Mbps to several hundreds of Mbps (cf. USAF's High Data Rate Airborne Terminal (HDRAT) with rates planned up to 274 Mbps).

3. The Use of Satellites by Military Users

As shown in Figure 4, there are 3 levels of satellites that can be used by military users:

- Level 1 (core) covers the most resilient systems that play a strategic role and feature a range of specific military protection measures such as anti-jamming and hardening. They all operate in so-called MilSatcom bands (EHF, X).
- Level 2 (security focused) covers the systems that support military, governmental and quasi governmental requirements that do not require the levels of assurance and resilience (and therefore cost) provided at level 1. Some systems will include resilient features, but generally only where these do not drive the cost of the system. They all operate also in so-called MilSatcom bands (UHF, X, Ka) which provides their key attribute of assured access to government users because commercial access is not permitted. HiCapS systems typically belong to this level.

- Level 3 (civil focused) covers systems that are designed primarily for civilian / commercial use, but can be used to fulfil requirements not requiring the levels of assurance and protection afforded by the first two levels. Here capacity tends to be optimised towards the population centres, or assumes usage profiles based on economic precedents. These systems are not designed for, and therefore struggle to cope with, the very high localised usage associated with military deployments into an operational theatre. HTS systems always belong to this level.

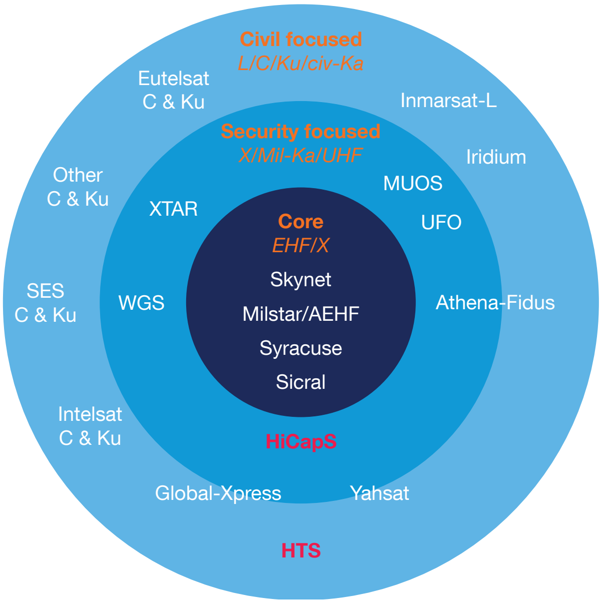

Figure 4: Satellites in the military context

4. Comparing HTS and HiCapS

4.1. From a spectrum access point of view

Even though the ITU does not distinguish between ComSatcom bands and MilSatcom bands (for the ITU, both are allocated to the Mobile Satellite Service (MSS) and/or to the Fixed Satellite Service (FSS)) there is, in many countries, a de facto partioning of Ka-band as far as Satcom is concerned:

- The 30-31 & 20.2-21.2 GHz ranges for government systems, with no or very controlled access for non-governmental users.
- The 27/27.5-30 & 17.3-20.2 GHz ranges for commercial usage.

4.2. From a terminal point of view

As of today, the majority of terminals (especially small tactical / COTM / airborne terminals) cannot operate simultaneously across both the commercial and governmental Ka satcom sub-bands. However, it is possible to exchange some components of the terminals to switch from one sub-band to another. As HTS and HiCapS systems typically operate in the different sub-bands transitioning from one system to the other is possible, but will require hardware changes. This is not the preferred approach for military users, especially those operating in remote theatres of operation with the associated challenges of logistics support. That said, HTS and HiCapS systems could be complementary, e.g. using HTS systems in home countries (e.g. for training) or during transit (e.g. vessels / aircraft) where capacity constraints are less, converting to HiCapS systems in theatre where overall capacity demands will overload HTS systems, and in-theatre hubbing is desired.

4.3. From an application point of view

HTS systems are highly optimized for consumer broadband applications that are not time-sensitive and are typically characterised by low inbound data / high outbound data profiles. They rely mainly on proprietary systems (specific waveforms contention strategies...) allowing them to maximize aggregate throughput. These systems typically utilise a high

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data rate broadcast outbound link (received by all in a cell, each user extracting data specific to them) and a time division multiplexed inbound link (each user assigned a part of the available capacity for a short period). These systems rely on the bursty nature typical of internet access – and suffer the same problems when supporting large numbers of users – slow responses, stilted video streams and timeouts.

Some HTS operators will allow users to install their own equipment in the operator's gateways that can provide closed user groups, with user defined performance; such opportunities will need to remain within the operating envelope of the HTS system – all comms through the gateway station and throughput being governed primarily by the spectrum allocation / satellite transponder. This approach must also consider security boundaries and possible complexities associated with the system's network management system (NMS). Its also important to note that many of the cost advantages achieved through using the baseline contended services offered by a HTS system will be lost when 'user defined' equipment is installed in the operator's hub.

HiCapS systems operate like typical Ku-band FSS satellites, albeit with the opportunity for higher data rates and smaller terminals; users have considerably more flexibility to implement assured throughput links (essential for time sensitive applications like real-time video transmissions or UAV C2 links), and any type of data profile. It is worth noting that UAVs are characterised by very high inbound data / very low outbound data profiles – the reverse of applications HTS systems are optimised for. HiCapS can also generally support any type of physical topology (mesh, star, intra-spot, inter-spot ...).

This indicates that Military users must carefully consider their needs and specify them in a way that ensures the correct system is selected.

4.4. From a coverage point of view

As depicted in Figure 5, HTS systems are targeting mainly land-masses with some areas better served by HTS systems than others. Except for one planned system that will be global by construct, HTS systems will never be global, even though some form of roaming is implemented (assuming they rely on the same proprietary standard).

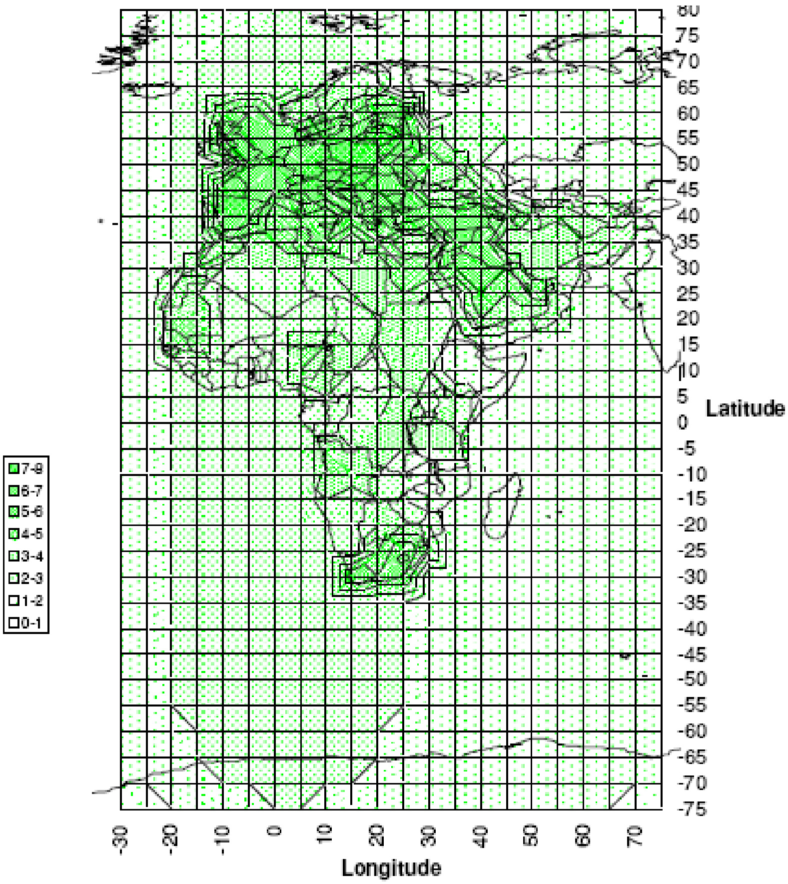

Figure 5: HTS anticipated density over EMEA by 2013

Furthermore, changing the coverage of a HTS system might be technically feasible, but the entire coverage will have to be modified which – even if permissible from a spectrum coordination point of view - will have significant impact on the overall addressable market and business returns therefore is rarely done.

A HiCapS system has steerable spot beams allowing capacity to be directed on a beam by beam basis to any theatre of interest within the field of view of the satellite.

Consequently the regional intensity of capacity needs associated with a military deployment suggests HiCapS systems will be better suited to supporting military deployments – particularly for high capacity COTM / Airborne systems. HTS systems are however well suited for supporting 'business systems' deployed to support military operations or welfare needs – assuming the available systems have the capacity to support a significant but short to medium term increase in users.

4.5. From a capacity point of view

As previously discussed HTS systems rely on significant frequency re-use to provide their high aggregate throughput, but the bandwidth available per spot is usually no more than 250 MHz. HTS systems also typically feature smaller spot beams that HiCapS systems (~0.5° vs. ~1.5°), meaning that, as depicted on Figure 6, around 19 HTS spots will be required to cover the same area as a HiCapS spot. As a consequence, a HTS system could deliver more aggregate throughput over the coverage area of a HiCapS spot beam. However geographical clusters of users confined to an area within one of the HTS spot beams can only get access to at most 250 MHz, whereas HiCapS users similarly clustered could in theory access the full 1 GHz. Military operations tend to favour such clustering of a small number of high bandwidth users.

Figure 6 also highlights that, where a single user is a significant user of the capacity in any one beam, (e.g. a UAV at 30MHz in a 50MHz capacity beam) and where beam transitions are needed, only one platform could be supported per group of beams support that UAV's operations.

From a capacity point of view, HiCapS is favoured where very high throughput is required from relatively small geographic clusters of user terminals and also where there are high bandwidth single mobile users such as UAV's that may otherwise be transitioning between smaller beams.

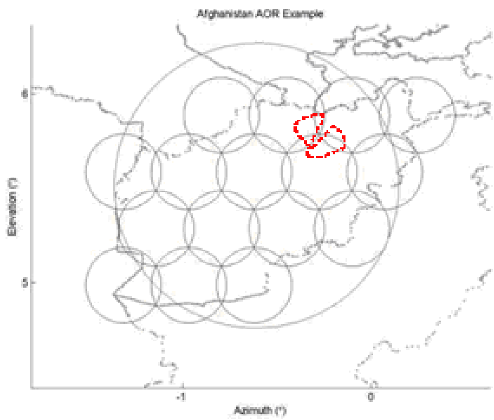

Figure 6

4.6. In summary

A number of possible selection criteria that may influence the choice of Ka systems have been reviewed, allowing a supplier to assess the suitability of HTS and HiCapS to meet each of them. Based on these selection criteria, HiCapS systems are generally better suited to military users, however each system has its merits and demerits and consequently the user applications have to be very carefully considered.

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5. Are HiCapS systems the panacea for military users?

There is clearly some enthusiasm in developing HiCapS. Apart from operating in the so-called military portion of Ka and providing a wide span (~ 2 GHz) of relatively congestion-free spectrum, one reason for this enthusiasm is that Ka-band (the next milsatcom band after X-band) enjoys a theoretical 'frequency squared' link gain advantage of about 11.5 dB compared to X-band. Though larger feed losses and inferior noise performance claw some of this back, the net gain advantage is about 8 - 9 dB on the uplink and about 5 - 6 dB on the downlink for antennas of comparable size. This means that, at least under clear sky conditions, higher data rates can be supported between terminals of the same size (this is confirmed by some initial tests we have conducted), or the same data rate can be supported between terminals with smaller antennas.

Unfortunately the link gain advantage is also eroded by more severe transmission losses at Ka-band compared to X-band. Certainly, if you are looking to achieve the ultra high availability of today's X-band links for all users (typically around 99.95%) then Ka-band is not for you[1]. However, if you are looking to achieve availability around 99%-99.5% for all users, the frequency-squared gain advantage easily exceeds the rain margins in all but the most tropical rain regions and generally leads to superior performance. Furthermore, adaptive coding and modulation (ACM) now allows us to avoid the need to operate with high fixed link margins such that the highest data rates can be supported when conditions are suitable.

6. Conclusion

This paper has reviewed the two primary types of systems that are emerging in Ka: those designed to serve asymmetric broadband applications typified by consumer and corporate internet access over a fixed coverage and those designed to serve applications requiring predictable, assured throughput and flexible coverage. Some comparisons have been provided in order to enable users to determine the types of application each system is best suited to support. HiCapS systems are generally more tailored to serve military users. However, each system has its merits and demerits and consequently the user applications have to be very carefully considered. The same point is also valid when comparing Ka-band with X-band, the other satcom band of choice for military users. There is no 'magic' system or band that will meet all user applications and therefore the choice of system needs careful consideration.

References

1. Jerry Goodwin, "C4ISR, Cyber Security, Robot platforms & Sensors Conference" (October 2009) (via Google)
2. WGCDR Nick Clarke, "MILCIS-2008" (November 2008) (via Google)

1. Ka can provide 99.95% for some users, e.g. by using ACM and prioritising traffic (minimum assured throughout for these users and best efforts for the other users).