ASIA-PACIFIC TELECOMMUNITY

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28 August 2021

ITU-APT Foundation of India (IAFI) [1]

FURTHER UPDATES TO WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT APT NEW REPORT ON DEVELOPMENTS IN INDUSTRIAL IOT APPLICATIONS USING SATELLITE TECHNOLOGIES

Background

At the 27th meeting, AWG had received one input contribution for further updating of the working documents towards a preliminary draft APT report on developments in Industrial IoT Applications Using Satellite Technologies (AWG-27/INP-29) which provided a compilation of the carried forward document from AWG-26 meeting (AWG-26/INP-19 and AWG-26/INP-58) submitted by Japan and Inmarsat Singapore.

The AWG-27 therefore updated the Working Document with an addition of Editor's Note on Section 5.4 due to the conflicting views on the relevance to include ESIM as part of an IoT applications since ESIM commonly use high-power and wide bandwidth. This is contradicting to IoT application characteristics that use low-power and narrow bandwidth. It was suggested that TG MSA should liaise with TG IoT on this matter and communication with relevant ITU-R study group is needed. Based on that, the meeting agreed that further review and discussion is required for this section at the next AWG meeting.

Discussions

It appears that the IOT using ESIMs may need a separate report and this it may be possible to separate the IOT using ESIM from this report.

Proposal

The contribution proposes that the ESIM related work may be separated from the IOT working document and further developed into a separate new AWG report. Towards this the material contained on ESIM in document AWG-27/TMP-28 has been moved to a new working document as Attachment 2 to this contribution to be started as a new work item under the satellite group in AWG-28.

This working document on Satellite IOT contained in AWG/TMP-28 in the attachment has been further updated and attached as attachment -1 to this contribution for further

[1] ITU-APT Foundation of India (IAFI) is a new Affiliate member of APT. Details of IAFI can be seen at itu-apt.org

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consideration by AWG-28

ATTACHMENT 1

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT APT NEW REPORT ON DEVELOPMENTS IN INDUSTRIAL IOT APPLICATIONS USING SATELLITE TECHNOLOGIES

1. Introduction

As 4G and 5G communication services are being deployed in Asia Pacific region, the usage of satellite communication servicesisan effective way of realizing IoTbecause satellite communication systems can bridge the regional information gap in the spread of terrestrial infrastructure. Moreover, applications using IoT technologies have also received attention in recent years in a variety of industries such as agriculture, medical care, disaster prevention, disaster response, and utilization of natural data. In particular, the improvement of production efficiency in some industries such as agriculture is expected by utilizing IoT technology that makes big data quickly accessible to users using satellites.

In order to develop and facilitate IoT technologies for a variety of industries in Asia Pacific region using satellites, this Report describes the introduction of future satellite technologies, sharing efforts and information within Asia Pacific countries using current and future satellites. The discussions on satellite applications will provide valuable information for APT members.

2. Scope

[Comment: This report provides information to develop IoT applications using satellites technologies for a variety of industries in the Asia Pacific region.]

This report is intended to support the adoption of IoT applications using modern future satellite technologies to enhance efficiencies in the Asia Pacific region's industrial sectors.

[This report should not duplicate works by ITU-R WP-4B and other ITU-R working parties.For reference purposes, only links to these documents to be included in this report in Section 4.5of this report.]

3. Vocabulary of terms

3GPP	:	3rd Generation Partnership Project
AESA	:	Aerodynamic Electronically Scanned Array
BSR	:	Buffer Status Report
CBB	:	Connection by Boeing
ESIM	:	Earth Stations in Motion

HAPS	:	High Altitude Platform Systems
HTS	:	High Throughput Satellites
IoT	:	Internet of Things
IMT	:	International Mobile Telecommunications
ITU	:	International Telecommunication Union
ITU-R	:	ITU Radiocommunication Sector
LPWAN	:	Low-Power Wide-Area Network
LTE	:	Long Term Evolution
MEC	:	Mobile edge computing
mMTC	:	Massive Machine Type Communication
M2M	:	Machine-to-Machine
NB-IoT	:	Narrowband Internet of Things
NFV	:	Network Functions Virtualisation
NGAT	:	Next Generation Access Technologies
NR	:	New Radio
NTN	:	Non-Terrestrial Network
PID	:	Proportional-Integral-Derivative
RB	:	Resource Block
SDN	:	Software-defined Networking
UAV	:	Unmanned Aerial Vehicle
UE	:	User Equipment
WRC	:	World Radiocommunication Conference

4. Modern IoT Applicationsusing Satellites

This section provides currently running applications and plans under considerationusing satellites, which realize the improvement of production efficiency in some industries

[Editor's Note*: Other applications based on input documents may be considered]*

4.1 Overview of Modern IoT Applications Using Satellite Technologies

Industries operate more safely and efficiently using satellite IoT applications, which enable real-time data access and monitoring nearly everywhere. Satellite technologies currently support several sectors including the agriculture, energy and critical infrastructure, manufacturing, ground transportation, aviation and maritime, and weather and environmental monitoring sectors.

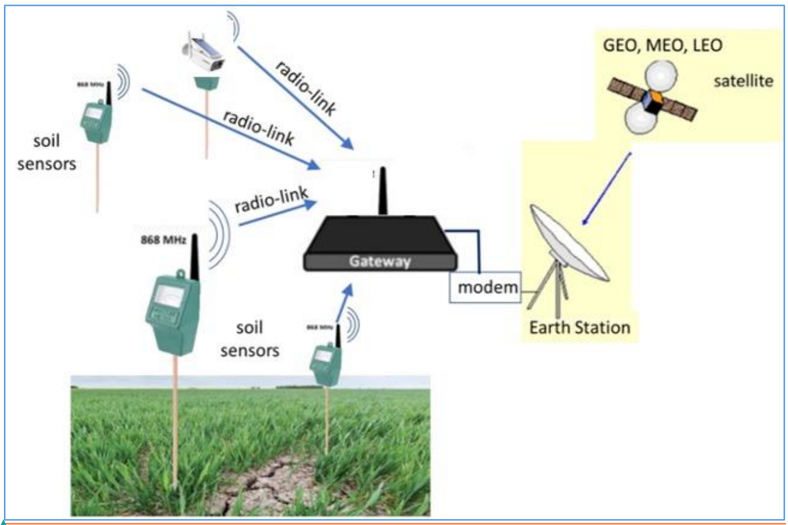
Modern IoT applications using satellite technologies allow industries to remotely monitor and more effectively manage both fixed and mobile activities. For example, satellite IoT can monitor the equipment status, operating parameters, environmental changes, energy consumption, and other metrics of fixed assets like electrical grids and machinery in manufacturing plants. They can also enable monitoring of mobile fleets of trucks, trains, planes, and ships, as well as personnel monitoring through wearables. These IoT applications help industries achieve cost savings, accelerated time-to-market, and improved safety.

There are two main types of IOT systems using satellite technologies:

1. **Type1 IOT system using Satellite network**

The **Type 1** satellite networks are where the IoT devices communicate between a "sensor" and a "base-station", using a low frequency/low power radio signal, and then the base station is connected to a satellite Earth station of any type (GEO, MEO, LEO);

Figure 1: Type 1 IoT System using satellite network



2. Type 2IOT system using Satellite network Those systems where the IOT device is directly connected to a satellite (or a constellation of satellites) via a satellite radio transmitter at the device itself.

Figure 2: Type 2 IoT System directly connected to the satellite(s)

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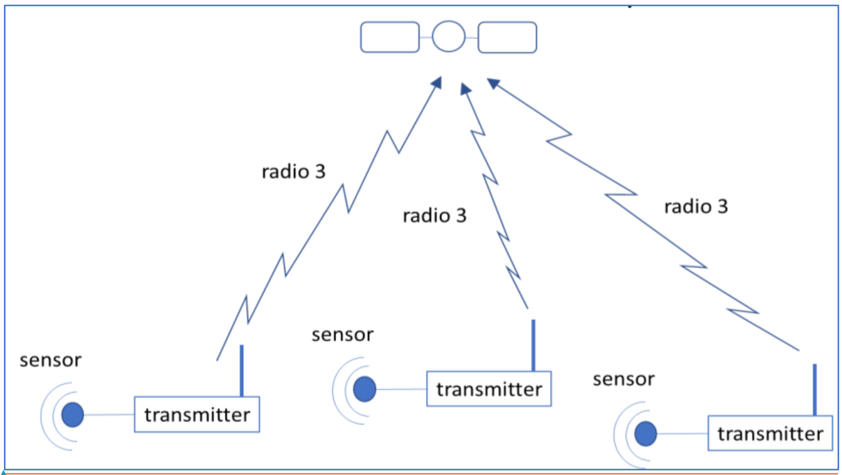

Both types of IoT systems are being deployed presently, and depending on which one is used, a different satellite system and frequency band is required for the proper operations of the system. Cost of the satellite terminals and their capacity, and latency could be the deciding factor for the selection of the appropriate satellite solution as the IOT devices are expected to be dispersed geographically and in large numbers.

It may be noted that:

- Satellite systems employed in **Type-1** IoT systems are best suited for NGAT and this allow the use of broadband satellite systems in all the orbits, i.e., LEO, MEO and GEO. This is most commonly used system today.

- Satellite systems employed in **Type-2** IoT systems are mostly using Low earth orbits about 1000 Km above the ground level.

The decision on which satellite systems are used is a financial (business model/cost model) one, and not a regulatory / legal one. Advancements in satellite technologies means that satellite technologies can deliver quality and affordable services to everyone and everywhere. Recent and upcoming HTS GSO systems with higher throughput and lower cost can provide economies of scale by serving the broader region, and NGSO systems which allow for very low latency for many real time IoT applications. These satellite technologies will complement GSO and current ground-based satellite services to fully support the Government's forward-looking vision of Digital India, ITU mission of removing the digital divide and providing

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broadband to all. In fact, despite the telecom revolution in India over the last decade, there is still a very significant portion of the Indian population living in remote and sparsely populated areas that lacks reliable and high-quality connectivity, which can be effectively addressed with the new satellite communication technologies.

In parallel, the direct to satellite model (**Type-2** IoT systems) is seeing new players that are deploying LEO constellations. They aim at addressing the specific needs of applications requiring ubiquitous connectivity from area not covered by terrestrial networks (such as: Earth's poles, oceans, deserts, rural areas, crop fields, earthquake monitoring, isolated industrial sites, etc.). This model also enables hybridization with terrestrial networks when the satellite connectivity is not the best option, for example in dense urban areas. In that case the end-user will integrate to its devices both satellite and LPWAN/NGAT connectivity that best fit its need. Again, we restate that the choice of a specific system architecture solution is that of finance (business/cost model) and the regulatory authorities should make it possible to allow all technologies to prosper and compete.

4.2 Modern Satellite Industrial IoT Use Cases

The subsections below identify several modern IoT applications using satellite technologies. This catalog is illustrative only and not intended to serve as an exhaustive list of use cases.

4.2.1 Agriculture

Satellite IoT can improve efficiencies in the agriculture sector through precision farming. Numerous environmental factors, large and small, affect agriculture operations. Satellite IoT enables the collection of extensive data on crops, livestock, and their environment. This includes data on light, humidity, temperature, soil moisture and nutrition, feed consumption, and more. Since most of the livestock are located in remote locations, satellite IoT have make it possible to track and monitor the farm animals automatically. The results inform farmers on how best to maximize their harvests in a sustainable manner.

For example, satellite IoT services are currently used to help fisheries gain highly specific data on the environment to optimize fish growth and minimize waste.[1] Satellite IoT capabilities enable fisheries to assess the water temperature, oxygen levels, and water currents in sea cages floating several miles offshore where there is no access to terrestrial service. This data is then used to determine the best time for feeding—one of the largest operational costs for fish farms—to minimize food waste.

Satellite IoT data also helps farmers to predict crop or livestock yields. To reduce unnecessary logistics and labor costs, supply chains can be adjusted to match the predicted harvest.

4.2.2 Energy, Critical Infrastructure and Mining

Satellite IoT has important applications for the energy and critical infrastructure sector, including power and water utilities, oil and gas, and mining. Situational awareness in these industries is essential. Satellite IoT provides continuous and real-time data necessary for informed decision making and improved safety.

Using satellite IoT, the energy and critical infrastructure sector can monitor expansive operations from a single location. This includes monitoring of power grids, pipelines, towers, tank measurements, equipment performance, and more that may extend throughout the region, as well as oil, gas, or mining activities in remote or offshore locations. Such monitoring minimizes the need for frequent and expensive visits to often dangerous sites to monitor activities.

Satellite IoT, for example, is currently used monitor active and reserve fuel tanks.[2] Many critical infrastructure sectors depend on fuel for ongoing operations or to support backup generators in the event of power outages, which can have a devastating effect on essential services. Fuel tanks and reserves must be monitored regularly for leaks to ensure adequate fuel stores. Rather than routinely dispatch workers to travel to and manually check fuel reserves, enterprises can use satellite IoT applications to monitor fuel levels in real time and issue a notification when fuel is low.This eliminates the risk of inaccurate fuel level readings from manual assessment. Enterprises further benefit from reduced costs as a result of improved efficiencies.

Satellite IoT applications also provide safety benefits. In the case of mining, IoT solutions can monitor air and water quality, acid mine drainage, and other effects from drilling and blast hole activities.[3] Additionally, IoT applications using current satellite technologies are used to enable real-time monitoring of the safety and performance of mine tailings dams.[4] Tailings dam failures in the Asia Pacific region can have tragic results including significant human and environmental losses. Energy and critical infrastructure enterprises can further monitor field teams and lone workers through wearables while they travel and work in the field.[5] An inactivity signal could alert emergency response that a worker has been injured or needs assistance.

4.2.3 Manufacturing

The manufacturing sector, particularly enterprises with operations based in rural areas, rely on IoT applications using satellite technologies to monitor machinery and systems. Applications support M2M diagnostics, providing real-time alerts and identifying maintenance needs. IoT sensors are also used to monitor conditions within facilities like heating, cooling, ventilation, and lighting. This reduces system maintenance costs in addition to reducing opportunity costs from system downtime. Enterprises further benefit from reduced energy consumption costs.

The sector can maximize supply chain efficiencies using IoT technology. For example, IoT monitoring enables predictive analysis to determine production volumes. This information can then be used to inform decision making down the supply chain, realizing efficiencies in packaging and distribution.

Large-scale manufacturing activities often require substantial space for physical operations. Satellite IoT services allow enterprises to base operations in rural areas where real estate costs may be lower without fear of being without connectivity.

4.2.4. Ground Transportation

From trucking to the railroad industry, satellite enabled IoT applications support many enterprises in the ground transportation sector.[6] IoT technologies allow for remote monitoring of fleets. Continuous fuel assessments and engine monitoring improve maintenance planning and provide for quick identification and response to unforeseen problems. Start and stop reports, idling notifications, and speed readings apprise enterprises of when to expect delivery or arrival. Weather and traffic sensors alert operators to conditions that may affect a shipping route in time to adjust the schedule or route selected. Improved efficiency and engine operations can reduce emissions and increase cost savings.

Satellite IoT applications can also be tailored to meet industry-specific needs. The rail industry can prevent derailments caused by root track problems by employing IoT sensors that measure track vibrations and other data points to identify deficiencies in the track or supporting mechanical components. The trucking industry uses data collected to evaluate driver performance and identify driver fatigue.

Satellite services provide IoT connectivity in parts of the region lacking terrestrial communications services. This is essential, as the ground transportation sector traverses throughout the Asia Pacific region and abroad.

4.2.5 Aviation and Maritime

The aviation and maritime sectors, which are critical for regional trade and transport, use satellite IoT applications to enhance both safety and efficiency.[7] [8] Large fleet operators can remotely track plane and ship operations in real time. Sensors monitor engine operations and conditions in the skies or sea. Such continuous monitoring allows operators to anticipate maintenance needs and environment trends and then respond quickly to irregularities. Gaining the insight on faults or problems before they become major results in fewer maintenance delays and improves overall operational and flight safety.

By maintaining systems and avoiding, where possible, harsh weather conditions,planes and ships run more efficiently. This reduces carbon emissions. It also reduces fuel costs, which comprise a significant portion of aviation and maritime operating expenses. Reducing fuel costs in turn enables these sectors to better compete with the ground transportation sector.

Opportunities exist to reduce regulatory compliance costs through IoT data gathering. Enterprises use satellite IoT applications to assess, record, and report fuel consumption or emissions, for example. They might also use IoT data gathering to demonstrate compliance with health and safety requirements for transport. Sensors can be used, for example, to monitor and record the temperature of cargo requiring climate-controlled transport.

4.2.6 Weather and Environmental Monitoring

Separate from Earth imaging services, satellite systems enable the collection of weather and environmental data through IoT. Sensors deployed throughout the region, even in the most remote areas, collect information on light, wind speed and direction, snow and rainfall, seismic conditions, temperature, biometric pressure, humidity, and other climate patterns. They also evaluate air quality.

Satellite IoT applications serve as a complement to terrestrial applications gathering data to support weather and environmental monitoring. The further reaching the IoT network, the more data available for experts to predict the cumulative effects of weather conditions. Satellite applications are necessary to collect data from remote areas, including at sea.

5. NewIoT Applications using Future Satellite Technologies

This section provides examples of the new IoT applications using future or existingsatellites

[Editor's Note: Other applications based on input documents may be considered]

5.1 Satellite 5G Technology

Future 5G networks will be a "network of networks" that use heterogeneous network technologies together to create a ubiquitous connectivity platform. Satellite technologies will be a key component of these future networks, as recognized by 3GPP in its ongoing standardization efforts related to 5G. Work is underway at 3GPP now on the including of NTN, including satellite, in future 5G systems.[9] Integration of satellite technologies in future 5G systems will be essential to support new and enhanced deployments of 5G applications like NB-IoT and mMTC, which can connect thousands of "things" simultaneously. Only by leveraging satellite technologies will NB-IoT and mMTC applications be able to be deployed on a global scale. Tests of satellite 5G NB-IoT services are already underway, and will be contributed to the ongoing 3GPP standardization work. [10]

5.2 Industry Automation and Remote Control

As described above, IoT applications using current technologies already improve efficiency and safety in fields like agriculture and transportation (among others) through remote monitoring that enables better decision making. In the future, advances in remote sensing capabilities will increase the amount of data collected, which can be leveraged to support automation and remote control capabilities. In the agriculture sector, for example, certain IoT transmissions could trigger automated operations such as irrigation, pesticide, or fertilizer application at optimal times and in precise amounts. In the medium to long-term, this even extends to robotics being used for field operations rather than people driving tractors. For the downstream supply chain, greater monitoring of the world's food supply in transit, whether on land, sea or air will help reduce food waste and losses, by maintaining optimum conditions (e.g. temperature and humidity) and optimising logistics routes. [11]

While IoT automation will begin incrementally and in isolated use cases, the future is one of greater automation, being able to run these assets intelligently and safely with less human intervention (and human error). Autonomous trains do exist today, including in the Asia-Pacific Region. [12] The future is for more of this according to harmonised standards. However, ubiquitous coverage and high-capacity connectivity provided by satellite services could potentially support autonomous shipping by rail or sea globally, including far beyond the reach of current terrestrial networks. [13].

5.3. IoT Applications using Satellite-NGAT Integration

5.3.1. Background of Satellite-NGAT Integration

Conventional satellite communication has its role in services that make use of the characteristics of wide area and multicast / broadcast, emergency communication in the event of disaster, or broadband services to mobility such as ships and aircrafts. In recent years, satellite communication system technologies have been progressed by the introduction of large-capacity satellites such as high-throughput satellites (HTS) using multi-beams, and mega-constellation consisting of many low-earth orbit satellites. With that, high-speed, large-capacity and flexible channel control, reduction of communications cost, and improvement of satellite services are expected.

For these situations, the integration of satellite communications into the Next Generation Access Technologies (NGAT) is being discussed in 3GPP [14] and ITU-R [15] on IMT-2020 requirements. Especially in Europe, joint projects between the public and private sectors are being actively carried out. The joint projects on the integration of NGAT and satellite in Europe aims to apply the following key NGAT technologies ~~of~~ into satellites.

- SDN (Software Defined Network)
  SDN is the technology to implement network configuration, functions, performance, etc. by software.
- NFV (Network Function Virtualization)
  NFV is the technology that extends virtualization to network infrastructure.
- Network slicing
  Network slicing is the technology realized based on SDN / NFV in which the network is virtually divided (sliced) according to service requirements such as low latency, high reliability, and high security.
- Orchestration
  Orchestration is the integrated management, control and optimization of network services and resources, which reduces the time required for the process by allocating networks and resources quickly and flexibly.
- Edge computing
  Edge computing is the technology to locate server at the vicinity of the user. It realizes low latency, large data processing, offload of terminal load.

Applying these technologies are expected to have a significant effect on satellite-NGAT integration.An assessment of some key elements, implementation of concepts and/or challenges to be considered for the Asia Pacific region has been reported [16]. A working group on satellite-NGAT integration has been held in Japan to discuss use cases, key technologies, standardizations [17]. The following subsections describe the uses cases and related key technologies discussed in the working group.

5.3.2. Examples of use cases for Satellite-NGAT integration

In the NGAT and beyond era (2020-2040), Japan will be faced with the serious issues to be challenged as follows.

- Population declines after peaking in 2005, and will be about 111 million in 2040
- Super aging society (consumer market occupied 40% by elderly people)

It is important to consider the abovementioned domestic issue and other social situations. There are various fields of use cases, but the following three categories where satellite utilization is expected in the future are studied such as “smart city”, “mobility”, and “emergency response”. Table 5.3.1 shows the expected use cases for IoT applications for each category.

Table 5.3.1.Expected use cases for IoT applications

Category	Expected use cases
Smart city	- Various data communication services using satellite terminals and base stations installed on traffic lights - Provision of information for tourists by natural environment monitoring - Autonomous driving (effective in rural areas due to population decline) - Expansion of NGAT area - Telemedicine - Autonomous robot - Use of satellite link to local/private NGAT (e.g. construction site) - Large-scale agriculture
Mobility	- Monitoring data collection of various devices on ship - High-speed, large-capacity, low-cost aircraft communications - Land-sea seamless connection in logistics systems - Autonomous driving - Flying car
Emergency response	- Landslides / dam monitoring, etc. - Collecting and providing natural disaster prediction information using distributed sensors - Disaster situation observation by IoT (when ground system cannot be used)

1. Smart city:
   This category is studied on the premise that spot service area would be created where there is no ground network, such as in rural areas. End users (services) include use at events, screening meters, monitoring, agriculture, forestry and fisheries, smart grids, telemedicine, etc. Service providers include government agencies, local governments, and communications carriers.
2. Mobility:
   End users (services) include ship / airlines / cars, passengers, and logistics. The entities involved include service providers, ship companies / airlines, and equipment manufacturers.
3. Emergency response:
   Disaster rescue and surveillance can be considered as use cases, but surveillance is the main use case for IoT applications. The end users include local governments. The service provider is a telecommunications carrier.

5.3.3. Related technologies for Satellite-NGAT integration

The effectiveness brought to users by the integration of satellite into NGAT, and the technology required for realization are described as follows for each category of use cases.

− Smart city:
  Regarding the effectiveness to users, it is expected that the simultaneous accommodation number of users will be improved by simultaneous control and data collection. It would be more effective for IoT-like data collection than high-speed communications. It is also expected that the transmission efficiency will be improved by selecting necessary data at the mobile edge computing (MEC) on the terminal side. If one terrestrial-satellite connection can be made seamlessly with one NGAT protocol, the switching time between terrestrial and satellite link will be reduced.

- Mobility:
  The effectiveness to users includes the improvement of efficiency for the operation management, internet connection, monitoring of ship / aircraft status, and container location information management for logistics. Since mobility are considered as users (terminals) and move globally, service continuity is indispensable, and network slicing is required to realize simultaneous large number accommodation, high speed, and large capacity.

- Emergency response:
  The effectiveness to users includes management of disaster victim detection and use of transmitting video information from the sky to the disaster response headquarters to check the situation in the disaster area. The content for monitoring is video, telephone call, data, data from an IoT sensing device, etc., and network slicing for each application can be set as a realization method. At that time, it is necessary to control the communications speed, delay, etc. in consideration of both the satellite and the terrestrial network. Backhaul system using UAV, HAPS, and satellite are considered as a network infrastructure.

[Editor's note: Section 5.4 has been discussed but not agreed, further discussion including to find the proper deliverables or to refine this section in the next meeting is required]

[Editor's note: Section 5.4 and related material has been moved to attachment 2 as a separate working document towards preliminary draft new AWG Report]

Broadband Satellite Communications for Aircraft and Ships

Introduction and Background

When ships are at sea or aircraft cross the oceans, they are out of reach of terrestrial networks. The airlines and ship operators fit their fleets with HTS services, to provide continuous broadband connectivity for passengers and crews. In particular, at the World Radiocommunication Conference (WRC) held in 2015, broadband satellite communication using Earth Stations in Motion (ESIM) which communicate with the space station in geostationary orbit, became possible in some fixed satellite service (FSS) bands. In addition, it is expected that the bandwidth for the ESIM will expand under the operational conditions of the terrestrial services (fixed / mobile) protection, and further broadband services will be accelerated after WRC-19 which expanded the regulations for ESIM to additional frequency bands.

Until recently, satellite communications for aircraft and ships have been using frequencies lower than the Ku band, but in recent years satellite communications services using the Ka band are also emerging. For example, Inmarsat launched the Inmarsat GX service for ships and aircraft, providing up to 5 Mbps for upstream and 50 Mbps for downstream.

In Europe and the United States, satellite services using the Ka band which can provide higher speed services than the Ku band have been introduced since the satellite services using the Ku band lack sufficient capacity for present needs.

Satellite Communications to ship have changed from analog communication in the 1980s to digital communication at present, and the communication speed has evolved from several kbps to over 10 Mbps. The frequency band used is the L band which has been used in the past, and recently the Ka band has been used for high speed communication.

Among satellite communications for mobiles, the demand for broadband services especially for aircraft is increasing due to the spread of smartphones and tablet PCs. The demand for air passengers is expected to increase worldwide, including in Asia, and in the next 20 years, the number of aircraft will increase from about 24,000 to about 41,000, and the number of new production aircraft is expected to be 35,000 [18].

On the other hand, since 2010, communication services such as Wi-Fi connections have been rapidly expanding in aircraft, and it is estimated that by 2022, the number of aircraft equipped with in-flight Wi-Fi services will be about 50%. Given these expectations, satellite communication services for aircraft are expected to increase in the future.

At present, the Ku band is mainly used as satellite communication services for aircraft, but the most satellites using the Ku band are basically for fixed satellite communications, in which the satellite beam is broad, and the communication speed is up to 500 kbps per unit, and the downlink is up to 5 Mbps.

On the other hand, recently, there has been a movement to improve the performance of satellites by using HTS satellites (High Throughput Satellites), which also employ multi-spot beams for Ku band satellites, and to reduce the size of terminals mounted on aircraft.

As described above, Ka-band satellites are being used for aircraft and ship communications in response to the demand for higher speeds and increased line capacity. However, since multiple communication services such as FS, FSS and IMT use the Ka bandin some countries of Asia Pacific region, it is essential to consider further frequency sharing and coexistence in the Ka band

Broadband services for aircraft

In aeronautical communication, air-to-ground direct radio communication is also used. However, communications using geostationary satellites enables communication over a wide range of the earth, including the sea, excluding polar regions, Inmarsat has been providing L-band voice and low-speed communication services since the 1980s. In the 2000s, in response to the demand for high-speed communication due to the spread of the Internet, WRC-03 approved the allocation of part of the Ku band frequency to the aeronautical mobile service, opening the way for the use of Ku band satellite communications in aircraft, and in 2004 Ku-band CBB (Connection By Boeing) launched the service for the first time in the world. After that, Panasonic Avionics launched an aircraft broadband communication service in the Ku band. Currently, in the Ku band, Panasonic Avionics, GOGO, and GlobalEagle are developing services.

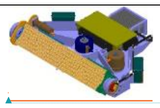
In the Ka band, Viasat started service in the United States in the 2010s. Viasat plans to launch three HTSs from 2019 onwards to cover the world. Inmarsat launched four HTS satellites covering the world by 2016, and launched the Ka-band service Inmarsat GX in 2017. Inmarsat provides an aircraft broadband service for business jets under the Jet Connex service name, and for passenger aircraft under the GX Aviation service name. SES also teamed up with Thales to announce the launch of an aircraft satellite communications service in the Ka band in 2016, and started services in North America from 2017. In the future, they plan to expand services by incorporating SES-17 and O3b mPower launched in 2017.

Table 5.4.1 summarizes the commencement years of Ka-band aircraft satellite communication services. In the mega-constellation plan to launch multiple satellites in low orbit, OneWeb, Space X, Telesat, etc. will be launched after 2020, and are expected to be used in the aircraft field.

Table 5.4.1. Commencement years of Ka-band aircraft satellite communication services

Service Name	Exede	JetWave/GX Aviation	FlytLive
Satellite operator	Viasat	Inmarsat	SES, Hughes
Service start year	2013	2017	2017

~~The currently used satellite communication antennas for aircraft services are of the type in which a rectangular planar antenna such as a horn array with an equivalent aperture diameter of about 40 cm is mechanically driven to direct the satellite regardless of the Ku and Ka bands. Another mainstream is a type that mechanically drives a parabolic antenna with an aperture of about 30 cm. The former is mainly mounted on the fuselage of medium-sized and large passenger aircraft, and the latter is mounted on the tail of small aircraft such as business jets.These antennas have a structure in which the antenna aperture is physically rotated. Therefore, it is necessary to secure a volume equivalent to the rotating sweep section in the radome. Therefore, the radome becomes large, and as a result, the aerodynamic resistance received by the aircraft tends to increase.~~
~~Against this background, a thin and low aerodynamic electronically scanned array antenna (AESA) type satellite communication antenna is appearing on the market, in the Ku band and Ka band, the product market will be launched in 2019. Figure 5.4.1 shows the satellite communication antenna for onboard aircraft.~~

~~**Planner antenna**~~	~~**parabolic antenna**~~	~~**AESA**~~
		
~~Height 20 cm~~	~~Height 40 cm~~	~~Height 3 cm~~

~~Figure 5.4.1. Satellite communication antenna for onboard aircraft~~

~~Related technologies for aircraft broadband service~~
~~[TBD]~~

5.4. Access Methods for IoT Applications

5.4.1. Background

Report APT/AWG/REP-89 “APT REPORT ON INTEGRATION OF SATELLITE TECHNOLOGY INTO THE NEXT GENERATION ACCESS TECHNOLOGIES ECOSYSTEM” provides information regarding study items in 3GPP TR 38.811[19], which describes the key impact areas for adapting the operation of the New Radio protocol to non-terrestrial (mainly to satellites) networks.After this report, the study of “Solution for NR to support non-terrestrial networks” started in 3GPP TR 38.821(Release 16) [19], intending for standardization in Release17. In 3GPP TR 38.821, technical studies and definition of related solutions are discussed.

5.4.2. Uplink Resource Allocation Method of LTE/5G NR-based Satellite-Ground Access Scheme Considering its Long Delay

As part of R&D activities in Japan, studies on uplink scheduling algorithm for long delay environments are being conducted [20]. The network architecture is assumed to provide bent-pipe links among airplanes, ships and ground stations equipped with LTE/5G station's capability (Fig. 5.5.1).

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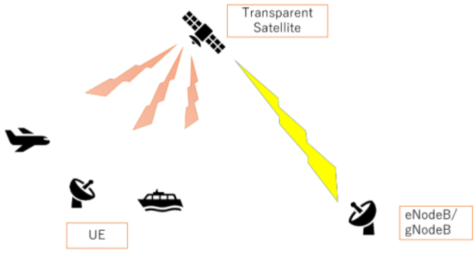


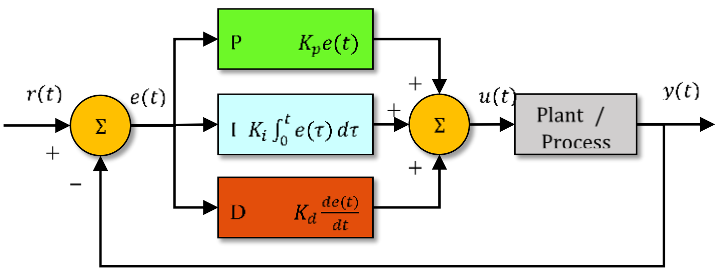
Figure 5.5.1. Network architecture with transparent satellite

5.4.2.1. Issues

Regarding the original LTE, to determine the resource block (RB) allocation for uplink, buffer status report (BSR) is the only information source to guess the current status of each UE's traffic demand.This mechanism has an assumption that the buffer status values always propagate immediately and the time lag between BSR and allocation is very small. However, in satellite communications, especially in the geostationary satellite bent pipe system, it takes 480msec to propagate for the satellite communications. Since instantaneous control is performed based on delayed information, appropriate allocation is not performed, and excessive resource allocation and insufficient resource allocation are likely to occur.

5.4.2.2. Proposed Method

The UE reports the average amount of arrival data to its transmission buffer instead of the amount of current data in the transmission buffer. The eNodeB securely allocates resources to UEs by PID control method (Fig.5.5.2). At the PID control, 'Resource Margin' is used as a control target. Here, the 'Resource Margin' means the difference between the amount of allocated resources and of the generated data.



r(t) = Average of arrivaltraffic bytes
e(t) = *r(t) – y(t)*
u(t) = Control result for resource allocation (bytes)
y(t) = Resource bytes allocated.

Figure5.5.2.Resource control by PID control

5.4.2.3. Performance Analysis via Network Simulations

As for the scheduling algorithms, Fixed, Proportional Fairness (PF) and Round Robin (RR) are chosen for the comparison of the proposed method. Fixed performs no resource coordination. Meanwhile, PF and RR are both typical scheduling algorithms. Table 5.5.1 shows the traffic model and TCP parameters. Fig. 5.5.3 is the simulation scenario and the network simulation setup. Broadband communication inside the airplane is assumed in this evaluation scenario.

Table 5.5.1. TCP traffic model (left), TCP parameters (right)

Parameter	Value
Traffic Size	3M bytes
Start Time	Uniform random value from 0 to 50 sec
Number of Occurrences	(a) 12 for each airplane (b) 8,17,14,6,20 for each airplane (c) 7,10,13,16,19 for each airplane (d) 5,9,13,17,21 for each airplane (e) 15 for each airplane
Number of Airplanes	5
Simulation Time	120 sec

Parameter	Value
TCP variant	HTCP
TCP send buffer size (byte)	100000
TCP receive buffer size (byte)	1000000
Initial congestion window	100
Max segment size (byte)	1000

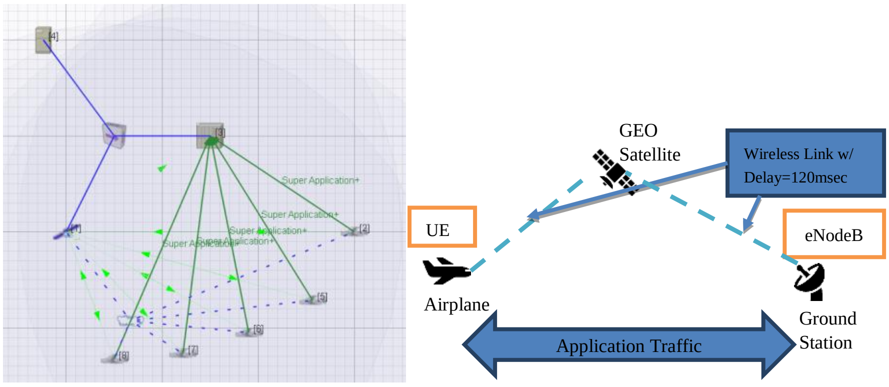


Figure 5.5.3. Simulation scenario on QualNet (left), Network simulation setup (right).

5.4.2.4. Simulation Results

The simulation results have shown that the proposed scheduler got the shortest delay compared to the traditional schedulers in all evaluation scenarios, assuming long delay environment (Table 5.5.2).

Table 5.5.2. Average traffic duration of 3Mbyte TCP application traffics for each radio resourcescheduling method (sec) (std. deviation)

	(a)	(b)	(c)	(d)	(e)
FIXED	17.66 (2.56)	25.32 (9.49)	22.63 (7.67)	25.14 (10.19)	21.68 (4.69)
PF	20.94 (4.15)	28.28 (8.68)	25.42 (7.11)	27.16 (8.36)	26.47 (6.12)
RR	18.26 (2.18)	22.53 (6.06)	21.08 (4.82)	22.14 (5.95)	21.87 (4.38)
Sat-SLA	16.42 (1.64)	17.29 (3.06)	17.32 (2.70)	17.21 (2.38)	20.28 (5.08)

Fig. 5.5.4 clearly shows that the more application sessions, the longer the average session duration (delay). Among the scheduling algorithms, the proposed SLA method always shows the best results regardless of amount of traffic.

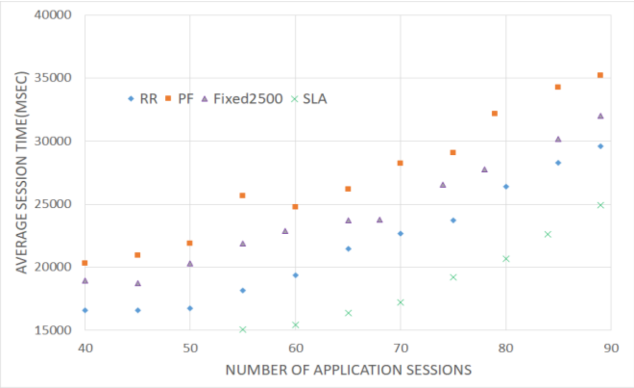


Figure 5

5.4.3. Conclusions

[TBD]

6. Conclusions

As exemplified in the existing and future use cases identified above, satellite technologies have an integral role in IoT connectivity. The Asia Pacific region can maximize the benefits of IoT capabilities by sharing information on and supporting deployment and adoption of satellite IoT services.

7. References

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ATTACHMENT 2

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT APT NEW REPORT ON DEVELOPMENTS IN BROADBAND SATELLITE COMMUNICATIONS FOR AIRCRAFT AND SHIPS

1.0 Introduction and Background

When ships are at sea or aircraft cross the oceans, they are out of reach of terrestrial networks. The airlines and ship operators fit their fleets with HTS services, to provide continuous broadband connectivity for passengers and crews. In particular, at the World Radiocommunication Conference (WRC) held in 2015, broadband satellite communication using Earth Stations in Motion (ESIM) which communicate with the space station in geostationary orbit, became possible in some fixed-satellite service (FSS) bands. In addition, it is expected that the bandwidth for the ESIM will expand under the operational conditions of the terrestrial services (fixed / mobile) protection, and further broadband services will be accelerated after WRC-19 which expanded the regulations for ESIM to additional frequency bands.

Until recently, satellite communications for aircraft and ships have been using frequencies lower than the Ku band, but in recent years satellite communications services using the Ka band are also emerging. For example, Inmarsat launched the Inmarsat GX service for ships and aircraft, providing up to 5 Mbps for upstream and 50 Mbps for downstream.

In Europe and the United States, satellite services using the Ka band which can provide higher speed services than the Ku band have been introduced since the satellite services using the Ku band lack sufficient capacity for present needs.

Satellite Communications to ship have changed from analog communication in the 1980s to digital communication at present, and the communication speed has evolved from several kbps to over 10 Mbps. The frequency band used is the L band which has been used in the past, and recently the Ka band has been used for high speed communication.

Among satellite communications for mobiles, the demand for broadband services especially for aircraft is increasing due to the spread of smartphones and tablet PCs. The demand for air passengers is expected to increase worldwide, including in Asia, and in the next 20 years, the number of aircraft will increase from about 24,000 to about 41,000, and the number of new production aircraft is expected to be 35,000 [1].

On the other hand, since 2010, communication services such as Wi-Fi connections have been rapidly expanding in aircraft, and it is estimated that by 2022, the number of aircraft equipped with in-flight Wi-Fi services will be about 50%. Given these expectations, satellite communication services for aircraft are expected to increase in the future.

At present, the Ku band is mainly used as satellite communication services for aircraft, but the most satellites using the Ku band are basically for fixed satellite communications, in which the satellite beam is broad, and the communication speed is up to 500 kbps per unit, and the downlink is up to 5 Mbps.

On the other hand, recently, there has been a movement to improve the performance of satellites by using HTS satellites (High Throughput Satellites), which also employ multi-spot beams for

Ku band satellites, and to reduce the size of terminals mounted on aircraft.

As described above, Ka-band satellites are being used for aircraft and ship communications in response to the demand for higher speeds and increased line capacity. However, since multiple communication services such as FS, FSS and IMT use the Ka bandin some countries of Asia Pacific region, it is essential to consider further frequency sharing and coexistence in the Ka band

2.0 Broadband services for aircraft

In aeronautical communication, air-to-ground direct radio communication is also used. However, communications using geostationary satellites enables communication over a wide range of the earth, including the sea, excluding polar regions, Inmarsat has been providing L-band voice and low-speed communication services since the 1980s. In the 2000s, in response to the demand for high-speed communication due to the spread of the Internet, WRC-03 approved the allocation of part of the Ku band frequency to the aeronautical mobile service, opening the way for the use of Ku band satellite communications in aircraft, and in 2004 Ku-band CBB (Connection By Boeing) launched the service for the first time in the world. After that, Panasonic Avionics launched an aircraft broadband communication service in the Ku band. Currently, in the Ku band, Panasonic Avionics, GOGO, and GlobalEagle are developing services.

In the Ka band, Viasat started service in the United States in the 2010s. Viasat plans to launch three HTSs from 2019 onwards to cover the world. Inmarsat launched four HTS satellites covering the world by 2016, and launched the Ka-band service Inmarsat GX in 2017. Inmarsat provides an aircraft broadband service for business jets under the Jet Connex service name, and for passenger aircraft under the GX Aviation service name. SES also teamed up with Thales to announce the launch of an aircraft satellite communications service in the Ka band in 2016, and started services in North America from 2017. In the future, they plan to expand services by incorporating SES-17 and O3b mPower launched in 2017.

Table 1 summarizes the commencement years of Ka-band aircraft satellite communication services. In the mega-constellation plan to launch multiple satellites in low orbit, OneWeb, Space X, Telesat, etc. will be launched after 2020, and are expected to be used in the aircraft field.

Table 1. Commencement years of Ka-band aircraft satellite communication services

Service Name	Exede	JetWave/GX Aviation	FlytLive
Satellite operator	Viasat	Inmarsat	SES, Hughes
Service start year	2013	2017	2017

3.- Antenna systems for on-board antenna

The currently used satellite communication antennas for aircraft services are of the type in which a rectangular planar antenna such as a horn array with an equivalent aperture diameter of about 40 cm is mechanically driven to direct the satellite regardless of the Ku and Ka bands. Another mainstream is a type that mechanically drives a parabolic antenna with an aperture of about 30 cm. The former is mainly mounted on the fuselage of medium-sized and large passenger aircraft, and the latter is mounted on the tail of small aircraft such as business jets.These antennas have a structure in which the antenna aperture is physically rotated.

Therefore, it is necessary to secure a volume equivalent to the rotating sweep section in the radome. Therefore, the radome becomes large, and as a result, the aerodynamic resistance received by the aircraft tends to increase.

Against this background, a thin and low aerodynamic electronically scanned array antenna (AESA) type satellite communication antenna is appearing on the market, in the Ku band and Ka-band, the product market will be launched in 2019. Figure 1 shows the satellite communication antenna for onboard aircraft.

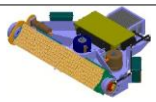
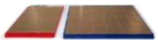
Planner antenna	**parabolic antenna**	**AESA**
		
Height 20 ㎝	Height 40 ㎝	Height 3 ㎝

Figure 1 Satellite communication antenna for onboard aircraft

3.0 Related technologies for aircraft broadband service

[TBD]

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