<8K 위성방송 융합서비스 워크샵>

위성 5G 연계 기술 동향

2019. 06. 20.
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Ajou University, Korea
Professor Jae-Hyun Kim

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- E-mail: jkim@ajou.ac.kr, Home Page: http://winner.ajou.ac.kr

Education

Experience
- Professor (Mar. 2003 ~present), ECE, Ajou University, Suwon, Korea.
- Member of Technical Staff, (Nov. 1998 ~ Feb. 2003) Bell Laboratories, Lucent Technologies, NJ, USA.
- Research Student, (Jan. 1996 ~ Feb. 1996) CRL(Communication Research Laboratory), Tokyo, Japan

Activities
- Chair, (2018 ~) 5G Forum, Smart City Expert Committee
- Center Director, (2018 ~) SICAS(Satellite Information Convergence application Service ICT Research Center
- Chair, (2012 ~ 2014) IEEE ComSoc., APB Information Service Committee

Awards
- Service Achievement Award from IEIE and KICS, KOREA (Nov. 17, Nov, 16)
- Best Journal Paper Awards, KICS (Nov. 17)
- Best Conference Paper Awards on KICS Conference (Jun 18, Jun. 17, Nov, 16, Jun. 15)
- IEEE SEOUL SECTION STUDENT PAPER AWARD 2016, Gold Best Paper Award (Dec. 16, Dec 17)
- Bronze Paper Award, ICEIC 2015, (Jan. 15)
연구실 소개

- **Current members : 12**
  - **Research professors**: 2 (김두환 교수님, 기충호 교수님)
  - **Ph.D students** 3 (정소이, 김경록, 강석원)
  - **MS/Ph.D Integrated students** 3 (천혜림, 김진기, 조준우)
  - **MS students** 2 (김송, 이원재)
  - **Intern** 2 (정홍제, 김태윤)

- **Alumni members : 34**
  - **Ph.D graduated students (11 people)**
    - 박우철, 오성민, 차재룡, 이현진, 강신현, 이충희, 김지수, 강정호, 고광춘, 이규환, 이승용
    - Work at ADD (Agency for Defense Development), NSRI (National Security Research Institute), ETRI (Electronics and Telecommunications Research Institute), KIDA (Korea Institute for Defense Analyses), KETI (Korea Evaluation Institute of Industrial Technology), LIG Nex1, Korea ARMY
  - **Master graduated students (23 people)**
    - 최승호, 이주아, 이성진, 오승환, 추상민, Saurabh Mehta, 안두성, 김신구, 박한준, 양희인, 김기훈, 김동욱, 김흥식, Nathnael Gebregziabher Weldegiorgis, 정현기, 최동열, 김현경, 유승수, 김홍무, Moonmoon Mohanty, 안창철, 이동학, 오지훈
    - Work at Samsung Electronics, LG Electronics, Hanwha Systems, Hyundai, Posco ICT, Solvit, TTA, Innowireless, and etc
Satellite communications History

- 1960: First passive communication satellite launched into space (Large balloons, Echo I and II)
- 1964: International Telecomm. Satellite Organization (INTELSAT) created
- 1979: International Maritime Satellite Organization (Inmarsat) established
- 1994: GPS 서비스 시작
- 2019. 02. 27 : OneWeb, Low Earth, USA
  - Ku-band operated, internet access at 50 Mbit/s downlink bandwidth
- 2019. 03. 15 : WGS-10, Geostationary, USA, Air Force
  - Ka-band and X-band transponders, offering downlink speeds of up to 11 Gbit/s
통신위성: Important Milestones – Domestic

1990’s

- 1995년 8월 5일: 무궁화 1호 (KOREASAT-1, 통신위성)
- 2006년 8월 22일: 무궁화 5호 (KOREASAT-5, 통신위성) 발사
  ✓ 최초의 민군 복합위성
- 2017년 10월 30일: 무궁화 5A호 (KOREASAT 5A) 발사
### Intelsat 38

<table>
<thead>
<tr>
<th>Nation</th>
<th>Azerbaijan, International</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type / Application</td>
<td>Communication</td>
</tr>
<tr>
<td>Operator</td>
<td>Azercosmos, Intelsat</td>
</tr>
<tr>
<td>Contractors</td>
<td>Arianespace</td>
</tr>
<tr>
<td>Equipment</td>
<td>Ku-band transponders</td>
</tr>
<tr>
<td>Configuration</td>
<td>SSL-1300</td>
</tr>
<tr>
<td>Propulsion</td>
<td>-</td>
</tr>
<tr>
<td>Power</td>
<td>2 deployable solar arrays, batteries</td>
</tr>
<tr>
<td>Lifetime</td>
<td>+15 years</td>
</tr>
<tr>
<td>Mass</td>
<td>3,500 kg (Launch)</td>
</tr>
<tr>
<td>Orbit</td>
<td>GEO, 45°C</td>
</tr>
<tr>
<td>Launch time</td>
<td>’18.09 (Intersat 38e)</td>
</tr>
</tbody>
</table>
Global Xpress (GX), Inmarsat 5 (I-5)

- 3 Geo Ka-band satellites (AOR, IOR, POR)
- Global coverage via 89 fixed spot beams (40 MHz ea) per I-5
- 6 steerable high capacity spot beams per I-5
- Fully operational in 2014

Satellite Access Stations (SAS)

- 6 SAS sites supporting global coverage and site diversity
- DVB-S2, multi-carrier MF-TDMA system
- QoS, multicast, IPv4/IPv6, dynamic routing, web acceleration, beam switching
- Security via AES-256, IPS 140-2

GX Markets

- Government
- Maritime
- Aeronautical
- Energy & Enterprise

GX User Terminals

- Terminal sizes from 30 cm to 1 m+
- Variants for GX markets
- Multiple vendors via 3rd party development kits
통신위성: Inmarsat Global Xpress (2/2)

Global payload
User Uplink: 29.5-30.0 GHz
User Downlink: 19.7-20.2 GHz
Feeder Uplink: 28.0-29.5 GHz
Feeder Downlink: 18.2-19.7 GHz

High Capacity Payload
User Uplink: 29.0-29.5 GHz
User Downlink: 19.2-19.7 GHz
Feeder Uplink: 27.5-28.0 GHz
Feeder Downlink: 17.7-18.2 GHz

Why Ka-band?
➤ 2.5 GHz of available spectrum
➤ Includes 2x500 MHz of spectrum exclusive to satellite
➤ Fewer operational satellites – simplify coordination
➤ L-band can be used to improve availability

➤ Uses adaptive coding and modulation to maintain link in rain-fade
➤ Maximum data rates: 5 Mbit/s uplink, 50 Mbit/s downlink for 60 cm (other terminals higher or lower)

※ Feeder link : 위성 – 중계기 또는 위성 – 게이트웨이 간 통신을 위한 양방향 무선링크
<table>
<thead>
<tr>
<th>Nation</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type / Application</strong></td>
<td>Communication  (Global Express)</td>
</tr>
<tr>
<td><strong>Operator</strong></td>
<td>Inmarsat</td>
</tr>
<tr>
<td><strong>Contractors</strong></td>
<td>Boeing</td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td>89 Ka-Band spot beams, 6 steerable spot beams, 72 transponders</td>
</tr>
<tr>
<td><strong>Configuration</strong></td>
<td>Spacebus-4000B2</td>
</tr>
<tr>
<td><strong>Propulsion</strong></td>
<td>Xeon ion propulsion system (XIPS)</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>2 deployable solar arrays (wing span: 40.6m) Batteries</td>
</tr>
<tr>
<td><strong>Lifetime</strong></td>
<td>15 years</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>~ 6100 kg</td>
</tr>
<tr>
<td><strong>Orbit</strong></td>
<td>GEO</td>
</tr>
<tr>
<td><strong>Launch time</strong></td>
<td>'17.05</td>
</tr>
<tr>
<td><strong>Nation</strong></td>
<td>United Arab Emirates</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Type / Application</strong></td>
<td>Communication</td>
</tr>
<tr>
<td><strong>Operator</strong></td>
<td>Thuraya Satellite Telecommunications Co.</td>
</tr>
<tr>
<td><strong>Contractors</strong></td>
<td>Boeing</td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td>L-Band 128 active elements, C-Band 2 active (2 spare), 12.25 m X 16m mesh reflector, 128-element diple L band feed array, 1.27 m round dual-pole reflector for C-band communications</td>
</tr>
<tr>
<td><strong>Configuration</strong></td>
<td>BBS-GEM (Geomobile)</td>
</tr>
<tr>
<td><strong>Propulsion</strong></td>
<td>R-4D</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>2 deployable solar arrays (40.4m), batteries</td>
</tr>
<tr>
<td><strong>Lifetime</strong></td>
<td>12 years</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>5250 kg</td>
</tr>
<tr>
<td><strong>Orbit</strong></td>
<td>GEO</td>
</tr>
<tr>
<td><strong>Launch time</strong></td>
<td>'08.01.15</td>
</tr>
</tbody>
</table>
<Globalstar – 2 >

<table>
<thead>
<tr>
<th>Nation</th>
<th>USA</th>
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</thead>
<tbody>
<tr>
<td>Type/Application</td>
<td>Communication</td>
</tr>
<tr>
<td>Operator</td>
<td>Globalstar</td>
</tr>
<tr>
<td>Contractors</td>
<td>Alcatel Alenia Space</td>
</tr>
<tr>
<td>Equipment</td>
<td>16 C-to-S-band transponders, 16 L-to-C-band transponders</td>
</tr>
<tr>
<td>Configuration</td>
<td>ELiTeBus-1000</td>
</tr>
<tr>
<td>Propulsion</td>
<td>-</td>
</tr>
<tr>
<td>Power</td>
<td>2 deployable solar arrays, 2.4 kW (bol), 1.7 kW (eol), batteries</td>
</tr>
<tr>
<td>Lifetime</td>
<td>15 years</td>
</tr>
<tr>
<td>Mass</td>
<td>700 kg</td>
</tr>
<tr>
<td>Orbit</td>
<td>1410 km</td>
</tr>
<tr>
<td>Launch time</td>
<td>’13.02.06</td>
</tr>
<tr>
<td>Nation</td>
<td>USA</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Type / Application</td>
<td>Communication, traffic monitoring</td>
</tr>
<tr>
<td>Operator</td>
<td>Iridium Communications Inc.</td>
</tr>
<tr>
<td>Contractors</td>
<td>Thales Alenia Space (prime), Orbital (integration)</td>
</tr>
<tr>
<td>Equipment</td>
<td>L-band payload, Ka-band cross-links, Ka-band downlinks, ADS-B payload, AIS payload (0n 58 satellites)</td>
</tr>
<tr>
<td>Configuration</td>
<td>ELiTeBus-1000</td>
</tr>
<tr>
<td>Propulsion</td>
<td>-</td>
</tr>
<tr>
<td>Power</td>
<td>2 deployable solar arrays, batteries</td>
</tr>
<tr>
<td>Lifetime</td>
<td>10 years (design), 15 years (planned)</td>
</tr>
<tr>
<td>Mass</td>
<td>860 kg</td>
</tr>
<tr>
<td>Orbit</td>
<td>780 km 86.4°</td>
</tr>
</tbody>
</table>
Follow the 8 launch missions

- Revamped the entire launch sequence for the 75-satellite constellation

<table>
<thead>
<tr>
<th>Launch date</th>
<th>Launch site</th>
<th>Launch vehicle</th>
<th>Satellite numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017.01.14</td>
<td></td>
<td>Falcon 9 FT</td>
<td>10</td>
</tr>
<tr>
<td>2017.06.25</td>
<td></td>
<td>Falcon 9 FT</td>
<td>10</td>
</tr>
<tr>
<td>2017.10.09</td>
<td>Vandenberg</td>
<td>Falcon 9 B4</td>
<td>10</td>
</tr>
<tr>
<td>2017.12.23</td>
<td></td>
<td>Falcon 9 FT</td>
<td>10</td>
</tr>
<tr>
<td>2018.03.30</td>
<td></td>
<td>Falcon 9 B4</td>
<td>10</td>
</tr>
<tr>
<td>2018.05.22</td>
<td></td>
<td>Falcon 9 B4</td>
<td>5</td>
</tr>
<tr>
<td>2018.07.25</td>
<td></td>
<td>Falcon 9 B5</td>
<td>10</td>
</tr>
<tr>
<td>2019.01.11</td>
<td></td>
<td>Falcon 9 B5</td>
<td>10</td>
</tr>
</tbody>
</table>
통신위성: OneWeb

- **OneWeb Satellite Constellation**
  - 600-satellite constellation (built out through the 2020)
    - To provide *global satellite Internet broadband services* to individual consumers
    - Initial limited service may begin as early as 2019
  - Expected to require up to US$3 billion in capital by the time the **full constellation** becomes operational in 2019–2020

OneWeb Satellite Stats

<table>
<thead>
<tr>
<th>Needed for Global Coverage</th>
<th>Satellite Production Rate</th>
<th>Start of Commercial Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;600</td>
<td>40/Month</td>
<td>2020</td>
</tr>
</tbody>
</table>

- Satellite Weight (Unit) | Propulsion System | Satellites per Launch Vehicle |
  - <150kg                 | Electric          | Up to 36
## Planet Labs Constellation

- By April 2019 the company had launched nearly 351 satellites, **150 of which are active**
- Planet operates **137 Doves, 5 RapidEye, and 15 SkySats** satellites

### Parameter Comparison

<table>
<thead>
<tr>
<th></th>
<th>PLANETSCOPE</th>
<th>RAPIDEYE</th>
<th>SKYSAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bands</strong></td>
<td>4 (RGB, NIR)</td>
<td>5 (RGB, red edge, NIR)</td>
<td>5 (RGB, NIR, pan)</td>
</tr>
<tr>
<td><strong>Products</strong></td>
<td>Color enhanced</td>
<td>Color enhanced</td>
<td>Visual</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td></td>
<td>Panchromatic</td>
</tr>
<tr>
<td></td>
<td>Analytic</td>
<td></td>
<td>Pan sharpened multispectral</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Analytic</td>
</tr>
<tr>
<td><strong>Pixel Resampled</strong></td>
<td>3 m</td>
<td>5 m</td>
<td>Visual, panchromatic, pansharpened multispectral: 0.8m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Analytic: 1m</td>
</tr>
<tr>
<td><strong>Positional Accuracy</strong></td>
<td>&lt;10 m RMSE</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>File Format</strong></td>
<td>GeoTIFF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Collection capacity**
- PLANETSCOPE: 200M+ km²/day
- RAPIDEYE: 6.5M km²/day
- SKYSAT: 400K km²/day

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<Constellation project>
Overview the Non-Terrestrial Networks in 5G System

Objective

- To study channel models, to **define the deployment scenarios** as well as the related system parameters and to identify and assess **potential key impact areas on the NR**
  - In a second phase, solutions for the identified key impact on RAN protocols/architecture will be evaluated and defined

Roles for Non-Terrestrial Networks in 5G System

Expect

- Upgrade the performance of limited terrestrial networks
  - **Un-served areas** that cannot be covered by terrestrial 5G network
    - Isolated/remote areas, on board aircrafts or vessels
  - **Underserved areas**
    - Sub-urban/rural areas

- Reinforce the 5G service reliability
  - Providing **service continuity**
    - M2M/IoT devices or for passengers on board moving platforms (e.g. passenger vehicles-aircraft, ships, high speed trains, bus)
  - Ensuring **service availability**
    - Critical communications, future railway/maritime/aeronautical communications

- Enable 5G network scalability
  - Providing **efficient multicast/broadcast resources**
    - Data delivery towards the network edges or even user terminal

---

### 5G Use Cases wherein Non-Terrestrial Network components have a role (1/2)

#### 5G use cases for Satellite access networks

<table>
<thead>
<tr>
<th>5G service enabler</th>
<th>5G Use case</th>
<th>5G Use case description</th>
<th>Satellite service</th>
<th>3GPP References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>eMBB</strong></td>
<td>Multi connectivity</td>
<td>• Users in underserved areas are connected to the 5G network via multiple network technologies and benefit from 50Mbps+&lt;br&gt;• Delay sensitive traffic may be routed over short latency links while less delay sensitive traffic can be routed over the long latency links</td>
<td>• Broadband connectivity to cells or relay node in underserved areas in combination with terrestrial wireless/cellular or wire line access featuring limited user throughput</td>
<td>TS 22.261&lt;br&gt;TR 22.863&lt;br&gt;TR 22.864</td>
</tr>
<tr>
<td></td>
<td>Fixed cell connectivity</td>
<td>• Users in isolated villages or industry premises access 5G services and benefit from 50 Mbps+</td>
<td>• Broadband connectivity between the core network and the cells in underserved areas (isolated areas)</td>
<td>TR 22.863</td>
</tr>
<tr>
<td></td>
<td>Mobile cell connectivity</td>
<td>• Passengers on board vessels or aircrafts access 5G services and benefit from 50 Mbps+.</td>
<td>• Broadband connectivity between the core network and the cells on board a moving platform (e.g. aircraft or vessels)</td>
<td>TS 22.261&lt;br&gt;TR 22.863</td>
</tr>
<tr>
<td></td>
<td>Network resilience</td>
<td>• Some critical network links requires high availability which can be achieved through the aggregation of two or several network connections in parallel&lt;br&gt;• The intent is to prevent complete network connection outage</td>
<td>• Secondary/backup connection (although potentially limited in capability compared to the primary network connection)</td>
<td>TR 22.863</td>
</tr>
</tbody>
</table>
## 5G Use Cases wherein Non-Terrestrial Network components have a role (2/2)

### 5G use cases for Satellite access networks

<table>
<thead>
<tr>
<th>5G service enabler</th>
<th>5G Use case</th>
<th>5G Use case description</th>
<th>Satellite service</th>
<th>3GPP References</th>
</tr>
</thead>
</table>
| mMTC               | Wide area IoT service | • **Global continuity** of service for **telematic applications based on a group of sensors/actuators** (IoT devices, battery activated or not) scattered over or **moving around a wide area** and **reporting information** to or controlled by a central server  
  - Automotive and road transport  
  - Energy  
  - Transport  
  - Agriculture | • **Connectivity** between IoT devices (battery activated sensors/actuators or not) and spaceborne platform.  
• **Continuity of service** across spaceborne platforms and terrestrial base stations is needed. | TS 22.261  
TR 22.861  
TR 22.862  
TR 22.864 |
|                   | Local area IoT services | • Group of sensors that **collect local information**, **connect to each other and report to a central point**. The central point may also **command a set of actuators to take local actions** such as on-off activities or far more complex actions  
• The sensors/actuators served by a local area network may **be located in a smart grid sub-system** (Advanced Metering) or **on board a moving platform** (e.g. container on board a vessel, a truck or a train) | • **Connectivity** between mobile core network and base station serving IoT devices in a cell or a group of cells. | TS 22.261  
TR 22.863 |

※ mMTC (massive Machine Type Communication)
# Channel model calibration (1/2)

## NTN channel model features per deployment scenarios

<table>
<thead>
<tr>
<th>Platform orbit and altitude</th>
<th>Deployment-D1</th>
<th>Deployment-D2</th>
<th>Deployment-D3</th>
<th>Deployment-D4</th>
<th>Deployment-D5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEO at 35786 km</td>
<td></td>
<td></td>
<td>Non-GEO down to 600 km</td>
<td>Non-GEO down to 600 km</td>
<td>HAPS between 8 km and 50 km</td>
</tr>
<tr>
<td>Non-GEO down to 600 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carrier Frequency on the link between Air / space-borne platform and UE</th>
<th>Deployment-D1</th>
<th>Deployment-D2</th>
<th>Deployment-D3</th>
<th>Deployment-D4</th>
<th>Deployment-D5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Around 20 GHz for DL</td>
<td></td>
<td></td>
<td>Around 2 GHz for both DL and UL (S band)</td>
<td>Around 20 GHz for DL</td>
<td>Below 6 GHz</td>
</tr>
<tr>
<td>Around 30 GHz for UL (Ka band)</td>
<td></td>
<td></td>
<td>Around 2 GHz for both DL and UL (S band)</td>
<td>Around 30 GHz for UL (Ka band)</td>
<td></td>
</tr>
<tr>
<td>Maximum Channel Bandwidth (DL + UL)</td>
<td>Up to 2 * 800 MHz</td>
<td>Up to 2 * 20 MHz</td>
<td>Up to 2 * 20 MHz</td>
<td>Up to 2 * 800 MHz</td>
<td>Up to 2 * 80 MHz</td>
</tr>
</tbody>
</table>

## NTN channel model features per deployment scenarios

<table>
<thead>
<tr>
<th>UE type</th>
<th>Deployment-D1</th>
<th>Deployment-D2</th>
<th>Deployment-D3</th>
<th>Deployment-D4</th>
<th>Deployment-D5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Handheld, nomadic, fixed, moving platform mounted</td>
<td>Handheld, moving platform mounted</td>
<td>Handheld, moving platform mounted</td>
<td>Handheld, nomadic, fixed, moving platform mounted</td>
<td>Handheld, moving platform mounted</td>
</tr>
<tr>
<td>Doppler cause</td>
<td>Mainly UE mobility</td>
<td>Mainly UE mobility</td>
<td>UE + satellite mobility</td>
<td>UE + satellite mobility</td>
<td>UE + HAPS mobility</td>
</tr>
<tr>
<td>O2I penetration loss</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Possible</td>
</tr>
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<td>Atmospheric absorption</td>
<td>Mandatory</td>
<td>Negligible</td>
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<td>Rain attenuation</td>
<td>Rain and cloud attenuation are not needed</td>
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<td>Cloud attenuation</td>
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<td>Negligible</td>
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<td>Scintillation</td>
<td>Tropospheric</td>
<td>Ionospheric</td>
<td>Ionospheric</td>
<td>Tropospheric</td>
<td>Negligible</td>
</tr>
<tr>
<td>Fast fading models (system level)</td>
<td>Flat fading</td>
<td>Flat fading or frequency selective fading</td>
<td>Flat fading or frequency selective fading</td>
<td>Flat fading</td>
<td>Frequency selective fading</td>
</tr>
</tbody>
</table>

Possible satellite and aerial access network architectures

Satellite access network & without ISL & above 6 GHz

Satellite access network & with ISL & above 6 GHz

Possible satellite and aerial access network architectures

- Satellite access network & below 6 GHz & with terrestrial access network

Satellite and aerial access network architecture principles (3/3)

- Possible satellite and aerial access network architectures
  - Aerial access network & without IAL & below 6 GHz
  - Aerial access network & with IAL & below 6 GHz

Non Terrestrial Network Design Constraints (Differences between NTN and NR)

- **Propagation**
  - Multi path, delay, Doppler
  - GSO: up to 272.4ms
  - NGSO: up to 14.2ms
  - HAPS: less than 1.6ms

- **Frequency plan and channel bandwidth**
  - S band (2~4 GHz, 2×15 MHz), Ka band (26.5~40 GHz, 2×800 MHz)

- **Cell pattern generation**
  - Larger cell, Moving cell (NGSO, HAPS)
  - Propagation Delay (cell Edge) >>> Propagation Delay (cell center)
Potential key impact areas on NR to support NTN (2/4)

- **Non Terrestrial Network Design Constraints**
  
  - **Mobility of the infrastructure’s transmission equipment**
    - Cellular network → usually fixed base stations (gNB)
    - NTN → moving base stations → higher Doppler effect (HAPS, NGSO)
    - LEO in S band (2GHz) ±48kHz Doppler shift
    - LEO in Ka band (20GHz) ±480kHz Doppler shift
    - LEO in Ka band (30GHz) ±720kHz Doppler shift
    - pre/post compensated

  - **Radio resource management** adapted to network topology
    - Access control
      - Cellular → gNB(Xn interface) → closed to the UE → **response time ↓**
      - Satellite system → satellite base station, gateway, hub level → **response time ↑**
      - → pre-grants, Semi Persistent Scheduling (SPS), grant free access scheme

- **Terminal mobility**
  - Support very high speed UEs (최대 1000km/h)

---

Non Terrestrial Network Design Constraints

- **Service continuity** between land-based 5G access and non-terrestrial based access networks
  - Support both non-transparent air/spaceborne (*on-board processing*) and bent-pipe architectures
  - **Handover preparation** and HO failure/RLF handling
  - **Time synchronization**
  - Measurement object coordination
  - Lossless handover support
  - Specifics related to intra-Non Terrestrial network mobility, as well as between Non-Terrestrial and Cellular networks

<table>
<thead>
<tr>
<th>Non-Terrestrial network specifics</th>
<th>Effects</th>
<th>Impacted NR features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion of the space/aerial vehicles (especially for Non GEO based access network)</td>
<td>Moving cell pattern</td>
<td>Hand-over/paging</td>
</tr>
<tr>
<td></td>
<td>Delay variation</td>
<td>TA adjustment</td>
</tr>
<tr>
<td></td>
<td>Doppler</td>
<td>Init synchro downlink</td>
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<td></td>
<td></td>
<td>DMRS time density</td>
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<tr>
<td>Altitude</td>
<td>Long latency</td>
<td>HARQ</td>
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<tr>
<td>Cell size</td>
<td>Differential delay</td>
<td>MAC/RLC Procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physical layer Procedures (ACM, power control)</td>
</tr>
<tr>
<td>Propagation channel</td>
<td>Impairments</td>
<td>TA in Random access response message</td>
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<td></td>
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<td>RACH</td>
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<tr>
<td>Duplex mode</td>
<td>Regulatory constraints</td>
<td>DMRS frequency density</td>
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<td></td>
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<td>Cyclic prefix</td>
</tr>
<tr>
<td>Satellite or aerial Payload performance</td>
<td>Phase noise impairment</td>
<td>Access scheme (TDD/FDD)</td>
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<td></td>
<td>Back-off</td>
<td>PT-RS</td>
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<tr>
<td>Network architecture</td>
<td>RAN Mapping</td>
<td>PAPR</td>
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<tr>
<td></td>
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<td>Protocols</td>
</tr>
</tbody>
</table>

Current satellite integration into 5G project - Europe

- SAT5G, SATis5, 5G-VINNI

Satellite into 5G & Standardization approach

- Short/Mid-term
  - Fully-fledged implementation for operational integration of satellite into the heterogeneous 5G “Network of networks” through plug & play approach with focus on higher layer enablers (SDN, NFV, Network Slicing, MEC, Security, etc) under common network management and orchestration

- Long-term
  - Possibility to use a 3GPP standardized version of 5G NR for the satellite waveform

SAT5G

Satellite and Terrestrial Network for 5G

Main objective

- To research, develop, validate and demonstrate key technology enablers for “plug-and-play” integration of SatCom into 5G networks, with focus on 5G use cases for enhanced mobile broadband (eMBB)

Other information

- Customer: European Commission (EC)
- Funding Programme: EC H2020 5G PPP Phase2
- Total Budget: 8.3 MEUR (100% funded)
- T0 Date: 01 June 2017
- Duration: 30 Month

SAT5G Use Cases Focus on eMBB 5G Usage Scenario

"Backhauling & Tower Feed"

"Trunking & Head-end Feed"

"Hybrid Multiplay"

"Comms. On the Move"

3GPP NexGen Core (5G Core Network)

Service Providers

Transport networks (Satellite, microwave, Millimetre wave Next Gen RAN, optical fibre, xDSL)

SaT5G Use Case 1: Edge delivery & offload for multimedia content and MEC VNF software

SaT5G Use Case 2: 5G Fixed backhaul

SaT5G Use Case 3: 5G to premises

SaT5G Use Case 4: 5G Moving platform backhaul
SAT5G Use Cases & Research Pillars

RP I: Implementing 5G SDN and NFV in satcom

RP II: Integrated SAT5G Network Management and Orchestration

RP III: Multi Link and Heterogeneous transport

RP IV: Common 5G-satcom Control Plane/User Plane Functions

RP V: 5G Security extensions to satcom

RP VI: Caching and Multicast for Content/VNF distribution to the edge over satcom
SATis5 (1/2)

Satellite and Terrestrial Network for 5G

- **Main objective**
  - To build a large-scale real-time live end-to-end 5G integrated network **Proof-of-Concept testbed** that enables the satellite terrestrial convergence into the 5G context. Focus on both **eMBB** and **mMTC** use cases

- **Other information**
  - Customer: European Space Agency
  - Funding Programme: ESA ARTES Advantage Technology (former ARTES 5.1)
  - Total Budget: 1.124 MEUR (100% funded)
  - Kick-Off Date: 01 Oct 2017
  - Duration: 24 + 12 months
  - Consortium
    - Prime Contractor: Eurescom (DE)
    - SES, Fraunhofer (FOKUS, IIS), Newtec, Universitat Munchen, Technische Universitat Berlin

SATis5 Use Cases in 5G

- SATis5 focuses on eMBB and mMTC usage scenarios for 5G

Testbed Architecture

- Backhaul Connectivity
- Indirect (proxy) Connectivity
- Direct to UE Connectivity

SATis5 Project Roadmap

- **Goal**
  - To have asap a minimal viable product (MVP) testbed in order to be able to create momentum for the results of the project
  - to be able to adapt and use the MVP in different use cases when needed

![Diagram of SATis5 Project Roadmap]

- Selection of the use cases
- Definition of the architecture
- Selection of the technologies
- Testbed planning
- Extension of the initial testbed with key technologies
- Over-the-air demonstrations
- Initial running testbed (MVP)
- Customization to use cases requirements
- Trials and validation completed
- Turn-key testbed for the verticals

**Testbed Development**
- Q4 2017
- Q1 2018
- Q2 2018
- Q3 2018

**Testbed Extension Phase**
- Q4 2018
- Q1 2019
- Q2 2019
- Q3 2019

**Testbed Support Phase**
- Q4 2019
- Q1 2020
- Q2 2020
- Q3 2020
- Q4 2020

Satellite and Terrestrial Network for 5G

Main objective
- Build an open large scale 5G End-to-end facility that can:
  - demonstrate that key 5G network KPIs can be met
  - be validated, accessed and used by vertical industries (e.g. in H2020 ICT-19 projects) to test use cases and validate 5G KPIs

Other information
- Customer: European Commission
- Funding Programme: EC H2020 5G PPP Phase 3
- Total Budget: 20 MEUR (100% funded)
- Kick-Off Date: 01 July 2018

5G-VINNI (2/3)

Key Objective

- Design an advanced and accessible 5G end to end facility for vertical industries
- Build several interworking sites of the 5G-VINNI end to end facility
- Provide user friendly zero-touch orchestration, operations and management systems for the 5G-VINNI facility
- Validate the 5G KPIs and support the execution of E2E trial of vertical use cases to prove the 5G-VINNI capabilities
- Develop a viable business and ecosystem model to support the life of the 5G-VINNI facility during and beyond the span of the project
- Demonstrate the value of 5G solutions to the 5G community particularly to relevant standards and open source communities with a view to securing widespread adoption of these solutions

5G-VINNI (3/3)

- Capability summary

**Norway (Oslo, Kongsberg)**
- Slicing (eMMB, URLLC, mMTC)
- E2E Service Orchestration (Nokia)
- NFVI (OpenStack) and MANO (Nokia)
- MEC (Nokia)
- Four 5G gNBs (Ericsson, Huawei)
  - 3.5GHz, 90MHz BW
  - 26GHz, 800MHz BW
- 5G Core (Ericsson)
- 3GPP compliance
  - Rel’15 in 2019, Rel’16 in 2021
  - NSA in 2019, SA in 2021
- Satellite backhaul option (GEO)

**UK (Martlesham)**
- Slicing (eMMB, URLLC, mMTC)
- Service Orchestration (Nokia)
- NFV MANO, NFVI and vEMS (Samsung)
- MEC
- 5G RAN incl. 3.5 and 26GHz (Samsung)
- 5G Core (Samsung)
- 3GPP compliance
  - Rel’15 in 2019, Rel’16 in 2021
  - NSA in 2019, SA in 2021

**Spain (Leganes)**
- Slicing (OSM extension)
- Service Orchestration (OSM NBI)
- NFV MANO (OSM) and NFVI (OpenStack)
- SDN (ODL/ONOS)
- Support for micro-VNFs
- 5G RAN (SDR), low frequencies and 30-300GHz
- Advanced monitoring and data-driven management
- Edge computing (MEC and non-MEC)
- 5G Core (possibly SBA-based)

**Greece (Patras)**
- Slicing (eMMB, URLLC, mMTC, via OSM)
- Service Orchestration (via OSM NBI services)
- NFV MANO (OSM) and NFVI (OpenStack)+DPDK
- 5G RAN open source radio (Lime, SRS)-700-800MHz, 3.5-3.8GHz
- 5G Core (Open5GCore)
- NB-IoT, LTE-M (FhG NB-IoT core)
- mmWave backhaul (Intracom)
- GEANT connectivity
- MEC

**Portugal (Aveiro)**
- Service Orchestration (Alticleabs)
- NG-PON2-based 5G front/backhaul (Alticleabs)
- NFVI (OpenStack)
- SDN (ODL)
- Cloud RAN
- MEC

**Germany (Berlin)**
- 5G RAN prototype(s)
- 5G Core (Open5GCore)
- Edge cloud/e2e Orchestration (OpenBaton)
- mmWave backhaul
- Interconnection with remote islands in Betzdorf and Tokyo
- Large scale events, Nomadic networks, Disaster Relief

**Germany (Munich)**
- 5G NR SA RAN (Huawei) 3.5 GHz
- 5G Core (Huawei)
- MANO and NFVI (Huawei)
- SDN (Floodlight)
- V2I, V2P
- MEC, Edge Computing
- URLLC targeting Rel16/17
- Sensor fusion enabled by 5G

**Luxembourg (Satellite Connected Vehicle)**
- GEO/MEO satellites (SES)
- C/X/Ku/Ka-band (SES)
- Satellite teleport (SES)
- Satellite backhauling (SES)
- Satellite 5G testbed node with SDN/NFV/MEC (SES)
- Satellite interconnection with Berlin Facility site (SES)
- eMBB, mMTC use cases (SES)
전세계 우주개발 경쟁: Space Race

- 미국의 위성 발사 수는 그 외 국가들의 총합과 비슷함
- 최근 2~3년 새에 중국이 러시아를 제치고 세계 2위의 위성 발사 국가가 됨

<Satellite launches by primary use and operating nation>

Current Trends in Satellite (2/5)

전세계 우주개발 경쟁 : 1966 vs. 2016

Countries with satellites
Space-launching countries with satellites

<Who has satellites? Then and now>

https://www.axios.com/the-state-of-the-space-race-in-1-chart-1516917901-0bf90c42-25c6-4c98-a29f-d000e43e342a.html
Current Trends in Satellite (3/5)

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Current Trends in Satellite (4/5)

- **전세계 우주개발 경쟁 : Budgets of different space agencies**
  - 2017년도 전세계 우주 개발 총 예산은 총 44 BUS$ (약 47조원)
  - KARI(한국)는 NASA, CNSA, ESA, ..., CSA, 다음인 세계 12위로 643 MUS$ (6,850억원)

Current Trends in Satellite (5/5)

- **Satellite industry budget**
  - 전체 예산 $348B 중 약 37%인 $128.7B가 satellite services
  - Satellite manufacturing 분야는 가장 큰 증가율 (10%)을 보임

- **Satellite manufacturing**
  - 2017 Revenues: $15.5B
  - 345 Satellites launched in 2017 included in study
  - 64 Commercially-procured launches
  - Non-U.S. $119.8B
  - U.S. $4.6B

- **Launch Industry**
  - 2017 Revenues: $4.6B
  - 64 Commercially-procured launches
  - Non-U.S. $119.8B
  - U.S. $4.6B

- **Ground Equipment**
  - 2017 Revenues: $108B
  - Consumer Equipment (GNSS devices/chips, satellite TV dishes, etc.)
  - Network Equipment (VSATs, gateways, etc.)

<The satellite industry in context>
Reusable Rocket Development (SPACEX)

- Recap of FALCON HEAVY and landing by SpaceX
  - 발사체 시스템 재사용으로 위성 발사 비용 감소

[8] https://www.youtube.com/watch?v=nqOU2CGeAvk
Earth Observation – Orbital Insight (1/2)

- Leverage advanced geospatial analytics to contextualize petabytes of multi-source data—including satellite and synthetic aperture radar (SAR) imagery, geolocation intelligence, and vessel traffic (AIS) data.

**Consumer**
- Retail & Wholesale
  - Vehicle Counts
  - Traffic Monitoring
- Import & Export
  - Asset Estimation
  - Investment Trusts
- Real Estate
  - Asset Management
- Transport & Logistics
  - Supply Chain Monitoring

**Energy**
- Upstream Oil & Gas
  - Exploration
  - Production
- Midstream Oil & Gas
  - Oil Tanker Shipping
  - Global Floating Roof Tanks
- Downstream Oil & Gas
  - Refineries
  - Retail Sales
- Power Generation
  - Power Plants
- Transmission
  - Transmission Towers
  - Natural Gas
  - Mining
- Renewable Energy
  - Solar Power
  - Wind Power
  - Hydropower
  - Biomass

**Insurance**
- Personal Lines
  - Underwriting and Renewals
- Commercial Lines
  - Building and Roof Detection
  - Marine Cargo Lots
- Catastrophe
  - Floods
  - Wildfires
  - Hurricanes
- Index Insurance
  - Natural Disaster Loss
  - Floods, and Crop Yields

**Financial Services**
- Investment Research
  - Equities
  - Commodities
  - Derivatives
  - Physical Assets
- Commercial Lines
  - Consumer Demand
  - Production and Distribution
  - Crop Health and Yield Estimates
- Multi-Asset Class
  - Trading
- Investment Banking & Private Equity
  - Mergers & Acquisitions (M&A)
  - Consolidations or Roll-ups
  - Divestitures
  - Carve-outs
  - Due Diligence
- Real Estate Investment Trusts
  - Asset Utilization and Monitoring
  - Traffic Density
- Investment Banking & Private Equity
  - Mergers & Acquisitions (M&A)
  - Consolidations or Roll-ups
  - Divestitures
  - Carve-outs
  - Due Diligence

**Public Sector**
- Intelligence
  - Mapping Demographic Shifts
- Defense
  - Asset Estimation
- Real Estate
  - Detecting Changes
  - Objects and Patterns

**NGO**
- Humanitarian Relief
  - Poverty Mapping
  - Refugee Movements
- Environmental Issues
  - Deforestation Monitoring
  - Deforestation Forecasting
  - Natural Disaster Response

Gain informational edge through **objective**, **transparent** and **timely** geospatial analytics.
통신분야의 위성군 프로젝트

Micro Sat, Nano Sat, Cube Sat 등 기술발전과, 통신/관측의 융합 서비스가 가능성을에서 주목을 받으며, 현재 다양한 형태의 중궤도 및 저궤도 위성통신 시스템 제안

✔ 브로드밴드 시스템
  • OneWeb, Starlink,
  • Leosat, O3b, mPower
  • ISIS, AISTECH,
  • Planet Labs

✔ 그 밖의 시스템
  • Sprie
  • LEOSAT
104 nano satellites (CARTOSAT) placed in the orbit successfully
SpaceX – Starlink constellation mission (05/12/2019)

- SpaceX launches 60 Starlink satellites, begins constellation buildout
  - With 60 satellites on board and at 227 kilograms per satellite
SpaceX – RADARSAT constellation mission (06/12/2019)

- SpaceX successfully launched the RADARSAT Constellation Mission
  - RADARSAT satellites are deployed 54, 58, 62 minutes after launch.
Huawei – VLEO satellite (1/2)

Massive VLEO Satellites
Very Low Earth Orbit (VLEO) Constellation

On-Board

UE

10,000 VLEO Satellites
300km (1ms one way latency)
5GHz Bandwidth

VLEO Revolution

Capacity for Single Satellite
- Data Rate Per Beam 19.25 Gbps
- Total Capacity per VLEO Satellite = 1.232 TBps

Total VLEO System Capacity
- VLEO total effective capacity = 1.18 Pbps

Area Capacity
- VLEO System uniform Coverage 2 Gbps/km²
- Per Beam Throughput : 32 Mbps /km²

VLEO Satellite Cost
- Each VLEO Satellite Launch Cost : $500k
- VLEO Satellite Cost : ~$600K

VLEO Constellation Cost
- Overall VLEO System Cost = $9.9B

Terrestrial Cellular Cost
- Total Terrestrial Cellular System Cost $450 B

Cellular/ VLEO = 0.8 per bit cost

Satellites of Future – Domestic

☐ 과기정통부 우주개발 시행계획 (2019년도)
  ➢ 우주개발진흥 시행 계획
    ✓ 발사체 기술자립, 인공위성 개발 활용(차세대중형위성 4호 개발), 우주탐사(달탐사), 한국형 위성항법(KPS : 예비타당성조사 신청 예정), 우주혁신 생태계(우주정거장 구축), 우주산업육성(소자급 우주부품의 국산화)

☐ 위성정보 활용 시행 계획
  ➢ 천리안 2A호를 통한 기상서비스 고도화
  ➢ 해양, 환경, 재난재해, 농림 등 국민생활과 밀접한 다양한 위성정보 서비스 제공
    ✓ AI, 빅데이터 첨단기술 접목하는 분석 서비스 및 차세대 산업 육성

☐ 우주위험대비 시행 계획
  ➢ 위성 추락 대응 매뉴얼 기반으로 재난대비 훈련 실시
  ➢ 감시 프로그램 개발, 인프라 확충

Consideration for satellite industry beyond 5G

☐ 위성시스템 개발
  ➢ 원격 탐지, 통신위성 등 활용 방안에 따른 위성체, 탑재체 개발 (Space Segment)
  ➢ 위성 발사를 위한 발사체, 위성 제어를 위한 지상 제어국 등 (Ground Segment)
    ✓ 주요 핵심 기술의 국산화 (고속통신 모듈, 탑재체(SAR), 안테나, HPA, 등)

☐ 위성단말 개발
  ➢ Mid-band spectrum (between 3.7GHz and 24 GHz)에서 동작하는 단말 (휴대폰, 위성 방송용 장비 등) 개발 [14]
    ✓ C-band (4 – 8 GHz), Ku-band (12 - 18 GHz), K-band (18 - 26.5 GHz)에 해당
      • 세계의 위성의 소형화에 따른 운용 대역이 높아짐
      • 미국의 경우, C-band 서비스로 rural connectivity, government services, tele-education 등에 활용할 전망

☐ 위성정보 활용 기술
  ➢ SAR 이미지, 영상 기반 해양, 환경, 재난재해, 농림 등에 활용하는 방안
  ➢ 위성정보 활용 가능 분야 검토
    ✓ New Business 플랫폼 구축

[13] Via Satellite article, “5G in the US: will satellite and mobile industries finally work in unison?”
Conclusions

- Communication Satellite Tendency
- Satellite Communication Standard
- Satellites of Future (SoF)

**Conclusion**

- **System**: miniaturization, cluster, cost-effective
- **Launch Vehicle**: reusable, cost-effective
- **Communication**: high-performance, cost-effective
References


[8] https://www.youtube.com/watch?v=nqOU2CGeAvk


[13] Via Satellite article, “5G in the US: will satellite and mobile industries finally work in unison?”
Thank you!

Q & A