SANSA: Shared Access Terrestrial-Satellite Backhaul Network enabled by Smart Antennas

SANSA: Hybrid Terrestrial-Satellite Backhaul Network for the 5th Generation

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With the contribution of the project partners

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Outline

- Motivation & Introduction.
- SANSA Objectives, Solution.
- Regulatory Analysis.
- Use cases and Scenarios.
- SANSA Key Enabling Components and Technologies.
- Demonstration
- Conclusions
<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Shared Access Terrestrial-Satellite Backhaul Network enabled by Smart Antennas</th>
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<tr>
<td><strong>Call</strong></td>
<td>H2020-ICT-2014-1</td>
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<td><strong>Type of action</strong></td>
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<tr>
<td><strong>Contract number</strong></td>
<td>645047</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
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<tr>
<td><strong>Start date</strong></td>
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<tr>
<td><strong>Estimated project cost</strong></td>
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<td><strong>Requested EU contribution</strong></td>
<td>2,983,930.00€</td>
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<td><strong>Total effort</strong></td>
<td>412 Person-months</td>
</tr>
<tr>
<td><strong>Project Coordinator</strong></td>
<td>Ana Pérez (CTTC)</td>
</tr>
<tr>
<td><strong>Project Officer</strong></td>
<td>Jorge Carvalho</td>
</tr>
</tbody>
</table>
SANSA Partners
Motivation

- Current studies predict an unprecedented mobile data traffic increase by 2020.
- Industry targets a 1000x capacity increase of mobile networks:
  - 10x more spectrum
  - 10x cell size reduction
  - 10x more spectral efficiency

Impose hard requirements to backhaul networks to be added to:
- Energy and spectrum efficiency
- Resilience
- Ubiquity
SANSA proposes a **self-organizing hybrid terrestrial-satellite backhaul network** operating at Ka band based on the following key principles:

- A seamless integration of the satellite segment into terrestrial backhaul networks.
- A terrestrial wireless network capable of reconfiguring its topology according to traffic demands.
- Spectrum coexistence between satellite and terrestrial segments.

*SANSA can be considered as a first step for the integration of terrestrial and satellite segments targeted in future 5G backhauling*
## Key performance indicators

<table>
<thead>
<tr>
<th>KPI</th>
<th>Target</th>
</tr>
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<tbody>
<tr>
<td><strong>Aggregated throughput</strong></td>
<td>Improvements over SoTA routing 20-30% of improvement over SoTA routing solution under dense backhaul environments.</td>
</tr>
<tr>
<td><strong>Backhaul network resiliency</strong></td>
<td>SANSA reconfigured network up and ready in &lt;10 seconds.</td>
</tr>
<tr>
<td><strong>Delay</strong></td>
<td>Per service type targets.</td>
</tr>
<tr>
<td></td>
<td>Expected improvements of up to 20-30% over SoTA routing solutions especially under backhaul environments.</td>
</tr>
<tr>
<td><strong>Spectrum efficiency</strong></td>
<td>10-fold improvement within the considered Ka band segments.</td>
</tr>
<tr>
<td><strong>Energy efficiency</strong></td>
<td>Up to 30% improvement compared to benchmark.</td>
</tr>
<tr>
<td><strong>Population coverage</strong></td>
<td>95-99% EU coverage</td>
</tr>
</tbody>
</table>
Ka band and more specifically bands 17.7 – 20.2 GHz for the downlink and 27.5 – 30 GHz for the uplink have been examined.

SANSA satellite terminals can be deployed in 2.9 GHz for the downlink (17.3 -20.2 GHz) and 1.38 GHz for the uplink (27.5 - 27.8285 GHz, 28.445 – 28.9485 GHz, 29.4525 – 30 GHz).

Antenna height ranges from 20 to 60 meters.

EIRP ranges from 20 to 50 dBW for P2P links in 18 GHz band

Channels are normally 7 MHz (widely used in UK), 14 MHz, 28 MHz (Most common) or 56 MHz.

Each P2P link has normally 1 or 2 carriers.

Distance of P2P links on the 18 GHz band is in the order of 20 Km.

The majority of antennas for P2P links have 3-4 degrees of beamwidth.

Antenna gains are usually around 32-39 dBi.
1-2. Radio Link Congestion or Radio Link Failure
3. New node deployment

- Rural environment

4. Remote cell connectivity

100% satellite backhaul
6. Moving platform (cruise ship)

Moving platform facilitating remote cell backhauling

Moving platform as a remote cell site
5. Content Delivery Networks (CDN) integration
## Scenarios

- **SANSA selected scenarios**

<table>
<thead>
<tr>
<th>Scenario ID</th>
<th>Spectrum Sharing</th>
<th>Satellite Carrier Bandwidth</th>
<th>Content Delivery Networks</th>
<th>Terrestrial Links</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DL only</td>
<td>UL+DL</td>
<td>SoTA</td>
<td>No CDN</td>
</tr>
<tr>
<td>Rural 1</td>
<td>✗</td>
<td></td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>Rural 2</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>Urban 1</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>Urban 2</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>Urban 3</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td></td>
</tr>
<tr>
<td>Maritime (Moving Platform)</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td></td>
</tr>
</tbody>
</table>
SANSA Key enabling components

- **Smart antennas**
  - With advanced beamforming capabilities (beam and multi-beam steering, null placement/steering, etc.)
  - Deployed in terrestrial nodes enabling:
    - Network topology reconfiguration
    - Spatial interference mitigation
    - Enabling spectrum coexistence (REM)

- **Hybrid network management**
  - Enabling the efficient use of all the network resources in order to improve capacity and energy efficiency. Enabling the self-organizing hybrid network
  - Consist of:
    - Centralized element (**Hybrid network manager**)  
    - Distributed element deployed in each node equipped with SANSA solutions (**Intelligent backhaul node**)
• 0 - Events manager at HNM detects (or is informed about) congestion or a failure
• 1 - The Topology Management Module check the RR Manager which resources are available for this node.
• 2 - A command is then sent to the terrestrial terminal (TT) to reconfigure its smart antenna.
• 3 – IBN of the TT receives the command and changes the beamforming weights
• 4 –The new link is activated
Demonstration

Laboratory Demonstration

- The evaluation scenarios aim at demonstration of the key enabling components and techniques for the shared access terrestrial-satellite backhaul network such as:
  - interference mitigation,
  - simplified prototype of smart beamforming antenna and
  - prototype of hybrid network manager.

Antenna Implementation

- Prototype of a smart antenna working in Ka band will be designed, manufactured and tested.
- The antenna should be able to reconfigure the main beam in addition to be able to change the pattern shape in directions other than the one selected for communication.
- One RF chain
- To guarantee the highest flexibility → hybrid digital/analog phased array.
- The hybrid nature of the phased array will enable the testing of several possible beamforming.
Demonstration scenarios

- Group #1: low cost and low complexity beam forming antenna solution for the microwave backhaul radio links to allow the terrestrial-satellite shared spectrum access.
  - One terrestrial-terrestrial link in co-existence with a terrestrial-satellite link over the air in Ka frequency band for different angular constellations between the both links.
  - The interference to the satellite-terrestrial links will be monitored during the demonstration.

- Group #2: performance of the hybrid terrestrial-satellite flexible backhaul network by including the main parts of the hybrid network manager and the intelligent backhaul nodes.
  - The multiple terrestrial-terrestrial as well as the satellite-terrestrial backhaul links and its interference will be emulated.
  - Link failure will be emulated to demonstrate the adaptive capabilities of the hybrid network
Conclusions

- SANSA is to boost the performance of mobile wireless backhaul networks and provide a solution for the backhaul of future communication systems to support the increasing traffic volumes.

- SANSA will improve capacity, energy efficiency and resilience against link failure or congestion while easing the deployment and assuring at the same time an efficient use of the spectrum.

- SANSA has two main enabling technologies, smart antennas (each node can communicate with many of its neighbors) and the hybrid network manager (allows efficient use of the all the network resources).

- To support spectrum coexistence: Novel interference mitigation techniques, Database-assisted shared spectrum techniques, and smart dynamic radio resource management (RRM) techniques for the shared terrestrial-satellite networks.

- A special care is devoted in SANSA to reduce the network energy consumption and to consider the delay in the satellite links.
Thank you for your kind attention!

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SANSA Objectives

- To increase the mobile backhaul networks capacity
  - Contributing to the 1000x increase by 2020

- To drastically improve backhaul network resilience against link failures and congestion

- To facilitate the deployment of mobile networks both in low and highly populated areas
  - Targeting 95%-99% European coverage

- To improve the spectrum efficiency in the extended Ka band for backhaul operations
  - Targeting a 10-fold spectral efficiency improvement within the considered Ka-band segments.

- To reduce the energy consumption of mobile backhaul networks
  - Targeting improvements in energy efficiency of up to 30%

- To strengthen European terrestrial and satellite operators market and their related industries

SANSA can be considered as a first step for the integration of terrestrial and satellite segments targeted in future 5G backhauling
1. Radio Link Failure
Demonstration

Group #2 Demonstration of the backhaul network and resilience capacity improvement enabled by the hybrid network manager

Traffic profile generator (applications, services, etc.) for multiple UE operation

Emulated Satellite channel (over-the-air)

Feeder link

Gateway

Evolved Packet Control (EPC)

Internet

SANSA-Shared Access Terrestrial-Satellite Backhaul Network enabled by Smart Antennas
Smart Antennas-SA

- Different modes of operation: Single and multibeam PTP or PTMP.
- Radiation null placement capabilities for interference mitigation
- The antenna requirements should depend on the part of the backhaul network addressed:
  - The number of simultaneous beams or collocated antennas should increase as we go from tail sites to core sites.
  - Single-beam reconfigurable antennas good for tail sites
  - PTMP antennas good for aggregation sites
  - PTP multibeam antennas good for aggregation and core sites.
- Low cost is a must (cost/beamforming capabilities tradeoff)
- Considered solutions: Hybrid analog-digital beamforming, Reconfigurable Reflectarrays and Parasitic arrays
Load balancing hybrid backpressure routing algorithms
- Energy-aware routing schemes (On/Off policies)
- Traffic classification
- Physical layer monitoring (detection of congestion/failures)
- Interface with beamforming antenna solution
Hybrid Network Manager-HNM

- **Topology management**: calculation of alternate topologies to counter-measure link events and improve the overall efficiency of the network. Distribution of new topology information to all nodes.

- **Configuration management**: Parameter modifications in satellite/terrestrial terminals at the remote iBNs

- **Events management**: reception of monitoring events sent by iBNs. Extract result actions derived from rules.

- **Radio resources management**: coordination of the radio resources (e.g. frequency spectrum) between the satellite and terrestrial links.
Enabling spectrum coexistence:
- Beamforming antenna solutions maximizing the cost-performance trade-off. Multi-BS, multicast,…
- Cognitive dynamic and hybrid radio resource management (RRM) techniques for the shared terrestrial-satellite networks.
- Database-assisted shared spectrum techniques: constructing Radio Environment Maps

Enabling the self-organizing hybrid network
- Self-organizing load-balancing algorithms aggregating the capacity offered by all terrestrial and satellite resources available at each backhaul node.
- Energy aware network reconfiguration and routing.
- Combination of multicast beamforming (from the satellite towards the terrestrial distribution network) with efficient traffic routing.