Integration of Satellite and LTE for Disaster Recovery

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Context

PPDR
Public Protection and Disaster Relief

Needs
To provide data-intensive communication in disaster scenarios

State of reality in the EU
- Different nations: different networks employed
- Old technologies
- Field operators often rely on commercial terrestrial networks
State of reality in the EU

Weaknesses of current solutions

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<th>Availability</th>
<th>- Terrestrial Infrastructure</th>
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<td>Non-negligible probability of disruption from disasters. Coverage subjected to profit logics.</td>
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<th>Data Rate</th>
<th>- Dedicated PPDR networks are slow</th>
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<tr>
<td>TETRA and Analogue PMR are the standard technologies; <strong>very good</strong> for advanced voice services, <strong>very bad</strong> for data-intensive applications.</td>
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<th>Resilience</th>
<th>- Commercial networks are not reliable</th>
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<td>Infrastructure-based systems are not redundant. They are vulnerable to disasters and subsequent incidents.</td>
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<th>Spectrum</th>
<th>- Interoperability</th>
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<td>No EU spectrum harmonization to date. Poses additional issues in cross-border operations.</td>
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LTE - satellite Integration

Key design requirements:

**Accessibility**
The deployed network(s) must be easily accessed by general UE.

**Coverage**
In absence of adverse external conditions, it must be possible to deploy IAN(s) where terrestrial coverage is disrupted or absent.

**Performance**
It must provide broadband access, at least to PPDR operators.

**Interoperability**
It should permit concurrent exploitation of existing terrestrial networks, if operative in the disaster area.
IAN provided by a MEOC is an **atomic** element with which to compose an ad-hoc *infrastructure-less* network topology.
Network architecture on a MEOC
Estimated LTE cell coverage in disaster scenarios

- Urban: 0.5 km $\leftrightarrow$ 1.5 km
- Suburban: 1 km $\leftrightarrow$ 2 km
- Rural: 1 km $\leftrightarrow$ 10 km

Satellite coverage depends on

- Constellation type (GEO, MEO or LEO)
- Number of satellites
- Design choices
LTE - satellite Integration [Data Rate]

LTE

- Theoretical: 326 Mbit/s in downlink, 75 Mbit/s in uplink
- Real Average: 17 Mbit/s $\leftrightarrow$ 33 Mbit/s

MEO Ka-band Satellites (O3b)

- 12 spot beams
- 1.2 Gbit/s each

Satellite LEO

- Increasing interest in Ka-band frequencies from LEO community
- Estimations of 3.75 Gbit/s
- Previous attempts FAILED, mainly for cost reasons
Specific voice capabilities

- From LTE Release 12 → Direct Mode Operation and Group Calls
- External platforms such as IP Multimedia Subsystem or Open Mobile Alliance service enablers
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Broadband data support

- High priority channels for FRs
- Low priority channels for people in distress (to at least provide them with basic communication capabilities)

↓

LTE BEARERS
Infrastructure-less vs Infrastructure-based Topologies
**Transparent handover provision**

- Through both S1 and X2 handover procedures
- The handling of the handover by the target eNodeB as seen from UE is exactly the same

**When to use what**

- X2 handover → UE is moving between terrestrial eNodeBs
- S1 handover → UE is moving between MEOCs cells or between a MEOC and a terrestrial eNodeB
Commercial European LTE networks are mostly deployed in:

- Band 3 (1800 MHz)
- Band 7 (2600 MHz)
- Band 20 (800 MHz)

NO EU HARMONIZED FREQUENCY BAND FOR PPDR PURPOSES
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Architecture may help

- MEOCs can be configured on place, in order to align the spectrum of deployed IANs with the frequency bands used by terrestrial networks in the specific geographical area of the disaster.
- Multimode UE may be adopted. LTE supports interworking and mobility with GSM, UMTS, CDMA2000 and WiMAX.
In general, FRs UE should be able to act as repeaters

We want to be able to provide coverage indoor, routing communication so as to make it reach a MEOC

2 Options

- Deploy Picocells or Femtocells inside buildings and tunnels, respectively
- Create a network chain by deploying the necessary number of FRs
End-to-end latency comparison between GEO and MEO satellite backhauls
TCP can create delay issues
TCP can create delay issues

Bufferbloat
- Too large buffers may cause issues instead of preventing them
- TCP acknowledges congestion only after the buffer fills
TCP can create delay issues

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TCP reaction times
- In wireless systems channel conditions can change very rapidly
- TCP reacts slowly and always interprets losses as congestion signals
We want to give guarantees!
Using Channel State Information, a node is able to assess if the assigned bandwidth can be fully exploited.
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**DyBRA: Dynamic Bandwidth Reservation Algorithm**

- CLIENT HELLO
- ACK HELLO
- ACK USED
- USED BW
- ACK HELLO
- ACK USED
$C^2ML+$ [Dynamic Bandwidth Management]
Disasters may be natural or **man-provoked**
In the latter case, there may be interest to cut out legitimate users from communication services
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QRM: Per-flow Queue Rate Management

Basic idea:

1. Detect a threat, i.e. if a node is sending packets at a rate greater than the allowed

2. Counteract the threat by dropping attackers’ packets ONLY
$C^2ML+$ [Resource Exhaustion Attacks]
$C^2ML+$ [Resource Exhaustion Attacks]

Drop Tail throughput

CoDel throughput

QRM throughput

Flow 1  Flow 2  Flow 3  Flow 4  Attacker
C²ML+ [Resource Exhaustion Attacks]

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Drop Tail queue

QRM queue

Good Flow RTT
Max Queue Occupancy

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Final Conclusions

Hybrid LTE-satellite architecture
- Easy connectivity
- Both infrastructure-less and infrastructure-based
- Almost ubiquitous coverage
- Resilient
- Fast

Resource Management: $C^2ML+$
- Middleware for Centralized and Cooperative resource management
- DyBRA for Dynamic Bandwidth management
- QRM for protection against Resource Exhaustion Attacks
Thank you for the attention

Any question?