Lunar Surface Communications

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Nokia Bell Labs

At Nokia Bell Labs we solve problems that address real human needs through the power of human intellect

As Nokia's award-winning industrial research lab, we innovate with purpose, pursuing responsible, sustainable technologies that have a demonstrable impact on society.

We have an unrivalled track record of driving innovation for more than 95 years that change the way we live, work and communicate.

Communications is crucial to future lunar economy

All future lunar deployments, economic and industrial activities need advanced voice, video, data and control communication solutions.

A standardized deployment, solution architecture and service provider will benefit all government, commercial and private stakeholders.

Image from NASA

Nokia Bell Labs pioneering innovations have been at the center of space exploration and deployable communications

Early 1960's

Developed Command Guidance Systems for Space Vehicles – 400+ missions & still operational

Created and manufactured Telstar 1 - the first communication satellite for TV broadcast (operated by NASA). Launched July 1962

Project Mercury – Bell Labs was responsible for system analysis and evaluation, control centers, astronaut training simulator, and consultation on various technical problems

Early 1970's

Gemini and Apollo – Bell Comm Inc 1962 for Planning & System Engineering

Mid 2000's

2005 - 2011 Developed & launched 9907 RDN entire 4G WiMax network in a box including access, core, mesh & MEC.

2015 Ultra Compact LTE Network (UCN) – backpack to airborne to near space comms

Current

2018 Vodafone Mission to the Moon – LTE Network for live-streaming HD video from Moon surface (not deployed)

High Altitude Balloons / Project Loon – LTE coverage from stratosphere

2020 - 2024 NASA Tipping Point – Developed end-to-end LTE Network (NIB, UE, O&M) for proximity communications on the Lunar Surface

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Why 3GPP (LTE & 5G) for lunar surface communications

Mature and proven technology
>4 billion LTE subscribers globally

Continually maintained and evolved
A technology used world-wide with ample support

Path to 5G
Well defined evolution path in 3GPP standards. User Equipment multi-RAT (LTE and 5G) support by default

An all-IP technology
Endless possibilities of integrations with other technologies and applications

Scalable
Bandwidth, data-rates, number of users, power, deployment options

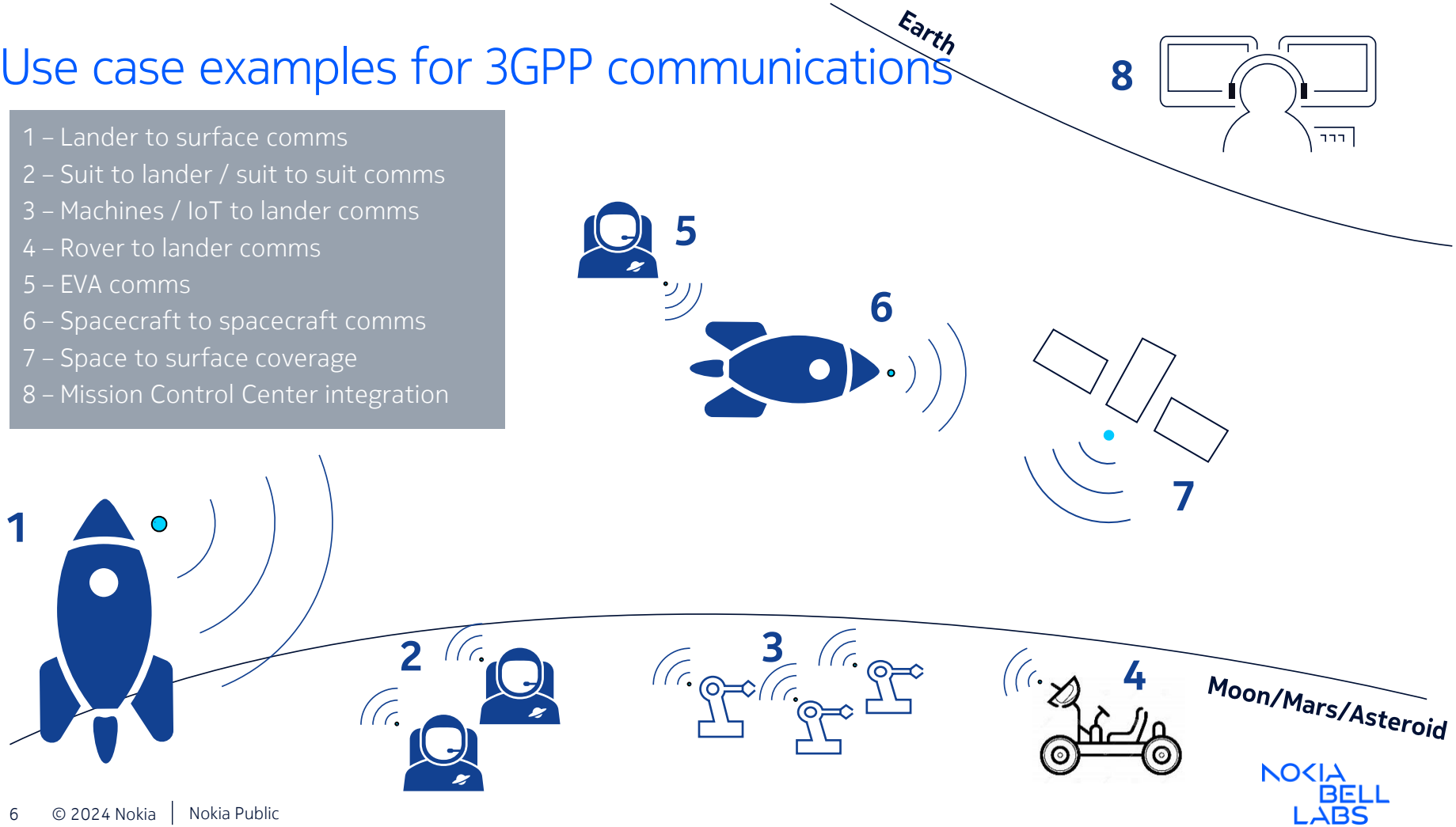
Robust technology
OFDMA-based, protection against multi-path, highly efficient

Mobility
From static users to high-speed mobility scenarios with seamless data handovers

Quality of Service
Built-in dynamic QoS enabling user, service and bearer differentiation, admission control, etc.

Use case examples for 3GPP communications

1 – Lander to surface comms
2 – Suit to lander / suit to suit comms
3 – Machines / IoT to lander comms
4 – Rover to lander comms
5 – EVA comms
6 – Spacecraft to spacecraft comms
7 – Space to surface coverage
8 – Mission Control Center integration



Lunar Surface Comms Evolution

From Custom Product to Commercial Service

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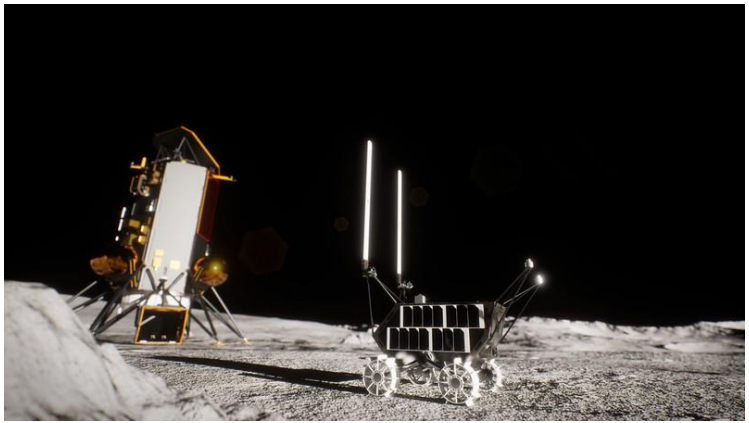
NASA selected Nokia to build first cellular network on the Moon

https://www.bell-labs.com/research-innovation/network-fundamentals/first-cellular-network-on-the-moon/

- Integrate Nokia's LTE/4G network assets onto Intuitive Machines' Nova-C lander and Lunar Outpost's MAPP Rover
- Deploy and establish an LTE/4G network on the Lunar south pole near the Shackleton Connecting Ridge
- Verify the LTE/4G network performance in short-range and long-range surface communications scenarios
- Enable advancement of the technology readiness of LTE technology and pave the way for future missions and commercial opportunities
- The target launch date is in late 2024 with a 12-day mission duration



Nokia will deploy the first LTE/4G communications system in space, providing critical communication capabilities on the lunar surface

Nokia LTE/4G lunar network key components

Rovers & Astronauts

LTE Radio Interface

Lunar Lander

Direct to Earth Link

Ground Station

Mission Control (Earth)

LTE User Equipment	**LTE UE Antennas**	**LTE BTS Antennas**	**LTE Network in a Box (NIB)**	**Ground Network Control**

Nokia LTE Solution Components

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What are some of the key challenges of deploying LTE in space?

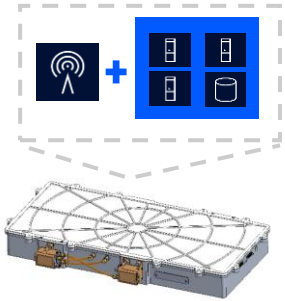
Environment

- Survival of launch, transit, landing and operations on the Moon
- **Thermal-mechanical design for space**

Radiation

- Single events upsets (SEU) caused by cosmic galactic rays, solar flares, multipactor
- **SW robustness features, HW modifications**

SWAP



- Size, weight and power need to be kept to the minimum
- **Integration of SW, lightweight HW components**

Remote Control

- Remote operation over long-latency, low-data-rate link
- **Custom Operations and Maintenance SW solution**

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3GPP-Enabled Systems Architecture

Key Design Principles

1. 3GPP lunar network should meet the initial lunar deployments and mission requirements while the architecture should be expandable and scalable to meet future use cases and requirements.

2. Each 3GPP lunar Network-in-a-Box (NIB) is assumed to contain all the necessary network elements and functionalities to be able to provide fully autonomous and independent coverage areas on the lunar surface.

3. Interoperability shall be maintained between lunar surface 3GPP network and other integrated technologies and architectures, based on industry standards.

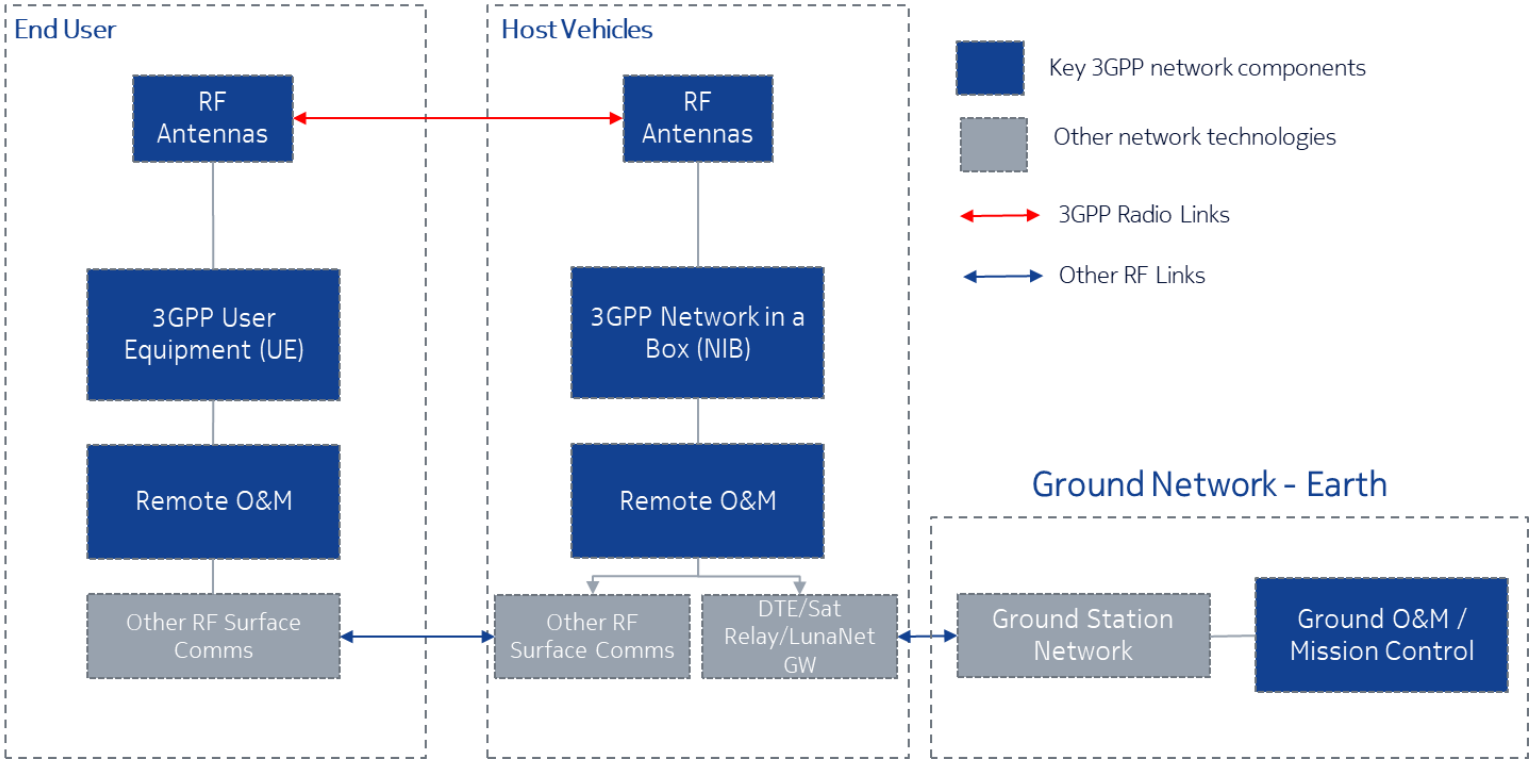
4. IP is the recommended baseline integration protocol.

5. Protocol encapsulation (DTN, CCSDS) is done on the host platforms where 3GPP network components are integrated.

6. Coverage & data-rates need to be qualified with RF simulations for each selected landing area or location on the lunar surface.

7. Networking layer should be as much as possible transparent to application layer.

High level system architecture

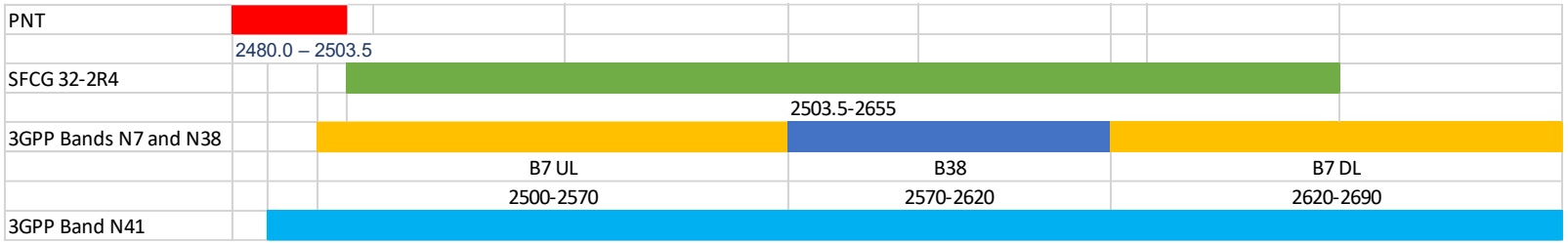


Spectrum considerations

Available spectrum below 6 GHz (1/2)

Per SFCG 32-2R5, best candidates are:

1. 2.5035 – 2.6550MHz: N7 (FDD, up to 35MHz BW), N38 (TDD, up to 40MHz BW), N41 (TDD, up to 151.5MHz)
2. 3.5000 – 3.8000: N48 (CBRS US)/77/78 (TDD, up to 100MHz BW)"



Usable for lunar deployment:

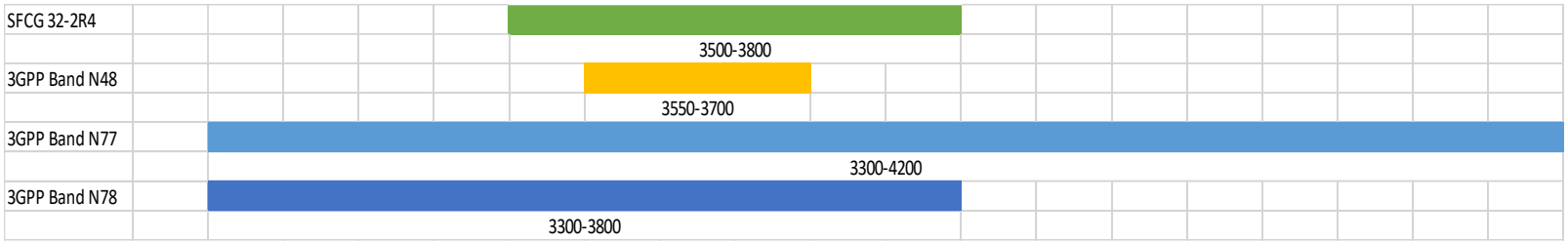
Band N7 (Moon)	2503.5-2570/2620-2655	(LTE and 5G, FDD)
Band N38 (Moon)	2570-2620	(LTE and 5G, TDD)
Band N41 (Moon)	2503.5-2655	(LTE and 5G, TDD)

Spectrum considerations

Available spectrum below 6 GHz (2/2)

Per SFCG 32-2R5, best candidates are:

1. 2.5035 – 2.6550MHz: N7 (FDD, up to 35MHz BW), N38 (TDD, up to 40MHz BW), N41 (TDD, up to 151.5MHz)
2. 3.5000 – 3.8000: N48 (CBRS US)/77/78 (TDD, up to 100MHz BW)



Usable for lunar deployment:

Band N48 (Moon) 3550-3700	(LTE and 5G, TDD)
Band N77 (Moon) 3500-3800	(LTE and 5G, TDD)
Band N78 (Moon) 3500-3800	(5G only, TDD)

Other regulatory considerations

1. In general, a 3GPP network deployment should follow SFCG 32-2R5 recommendations, including co-existence with other RF spectrum users. Further analysis and discussions are for future consideration, including alignment with national and international spectrum regulators.

2. In terms of Public Land Mobile Network (PLMN) ID assignations, IT T-REC E.212 already caters for Mobile Country Code (MCC) “999” for use in private networks. This PLMN can be used for the initial mission deployments.

3. Future network evolution with additional potential network service providers may require additional considerations and selections of other PLMN IDs, e.g., for roaming purposes, but this is for future study.

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