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Satellite Internet of Things: challenges, solutions, and development trends

Key words: Internet of Things; Satellite communications; Low Earth orbit (LEO); Massive connectivity; Random access

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Motivation

- Satellite Internet of Things (IoT) is a promising way to provide seamless coverage to a massive number of devices all over the world, especially in remote areas not covered by cellular networks.
- In general, satellite IoT networks take low Earth orbit (LEO) satellites as access points, which solves the problem of wide coverage, but leads to many challenging issues. That is, traditional LEO satellite communication techniques are not applicable for satellite IoT with a massive number of devices.

Main idea

1. Satellite IoT networks

- Network architecture
- Service characteristics

2. Challenges in satellite IoT

- Massive connectivity & wide coverage
- High mobility, low power, and stringent latency

3. Solutions to satellite IoT

- Access protocol
- Multiple access techniques

4. Development trends of satellite IoT

- Satellite-territorial integrated IoT
- Multi-LEO satellite cooperation
- Joint LEO and geosynchronous orbit (GEO) satellite access
- Convergence of satellite IoT and deep-space communication networks

1. Satellite IoT networks

1. Network architecture

IoT devices (e.g., sensors, cameras and controllers)

Gateways (GWs)

Access networks

Core networks

2. Service characteristics

Sporadic traffic

Small data

Massive packets

Heterogeneous requirements

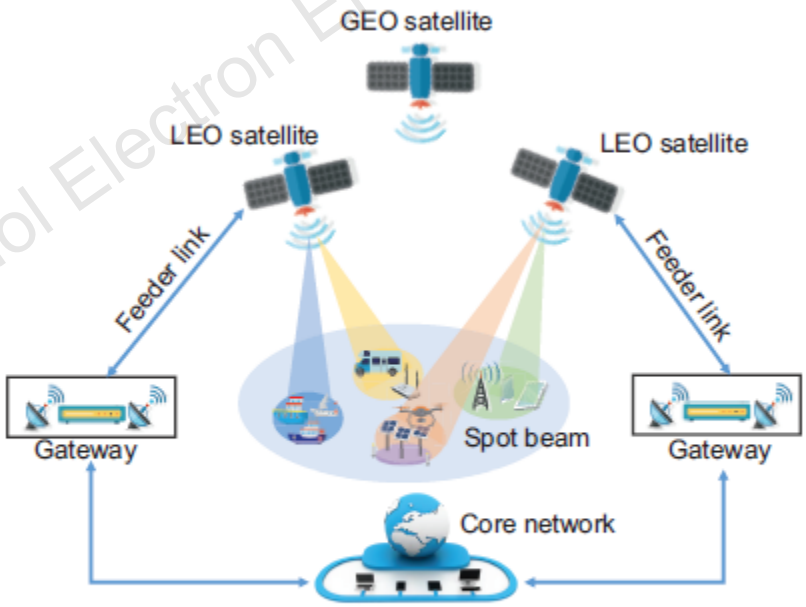

Fig. 1 A typical network architecture of satellite Internet of Things (IoT) (LEO: low Earth orbit; GEO: geosynchronous orbit)

2. Challenges in satellite IoT

Massive connectivity

- LEO satellites identify active devices from a massive number of devices, by multiple negotiations, resulting in prohibitive signaling overhead.
- It is difficult for orthogonal multiple access (OMA) to transmit a large number of data packets simultaneously over a limited radio spectrum.

Wide coverage

- Wide coverage based on multi-beam techniques is not trivial.
- Different propagation environments of IoT devices lead to complex precoder design.

High mobility

- A high-mobility LEO satellite leads to fast time-varying of the channel.

Low power

- Satellite IoT requires low power consumption at both the transmitters and the receivers.

Stringent latency

- Satellite IoT has a large delay, but some IoT services have stringent delay constraints.

3. Solutions to satellite IoT

1. Access protocol

- Grant-based random access protocols

  large signaling overhead, a high access failure probability, and significant delay

- Grant-free random access protocols

  compressive sensing (CS) based approaches

  covariance-based approaches

2. Multiple access techniques

- OMA techniques
- Non-orthogonal multiple access (NOMA) techniques

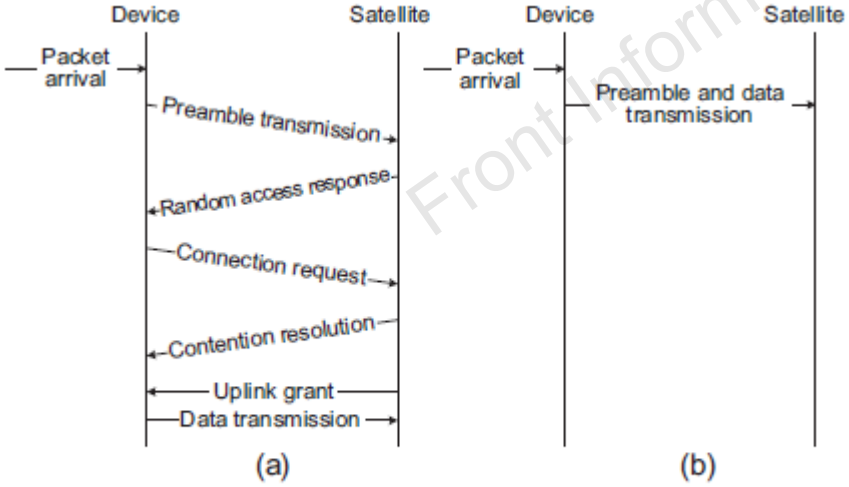

Fig. 2 Random access protocols: (a) grant-based; (b) grant-free

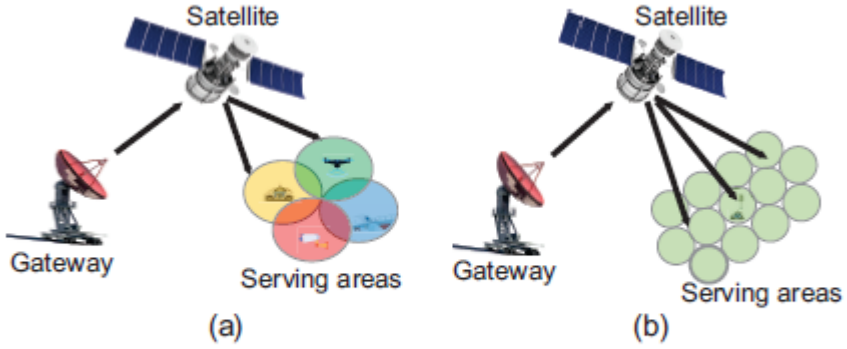

Fig. 4 Multiple access techniques: (a) orthogonal; (b) non-orthogonal

4. Development trends of satellite IoT

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Conclusions

- An introduction to satellite IoT networks was provided with an emphasis on the characteristics of IoT services.
- Various challenging issues in the design of satellite IoT were analyzed.
- An example of the design of satellite IoT from access protocols to access techniques was presented. The performance was shown through numerical simulations.
- Some development trends of satellite IoT were discussed.