

Lecture 25

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1 Earth observation

Satellites that observe the earth, taking pictures in:

- RGB
- RF
- microwave

Useful for: monitoring natural disasters, monitoring wars

Pico satellite: weigh 0.1 - 1kg. Sensors sends measurements directly to picosats, then ground station, so no gateway needed.

1.1 Impact of orbits

Low Earth Orbit: 500 - 1000km above earth surface

Pros:

- High resolution (1 pixel per m²)
- 90 minutes cycle, so more sample per day
- Low launch cost, large constellation (planet dove, 200 RGB satellites)

Cons:

- Low coverage

Benefit for IoT:

- Low latency
- High signal strength and low power, so more battery life

1.2 Data download bottleneck

Terabytes data per satellite per day, small window (few minutes) of satellite - ground station connectivity per day, so **delay of 6 - 24 hours**.

Problems: Long delay

Solution 1: more ground stations?

- Very expansive (millions)
- Licensing spectrum
- Low utilization (only using few hours per day)

1.3 Upload problems

IoT devices want to talk to satellites, lead to collisions.

IoT devices are cheap, low-power, and small, so it can't perform directional beams, has to **broadcast in wireless medium**.

1.3.1 Overlap and Medium Access

When one IoT device is in range of two satellites, should reduce the transmissions because it jams more medium. But by how much?

2 Distributed Ground Station (ground-station-as-a-service)

Few expansive ground stations, lots of small distributed ground stations.

”Service”: satellite pay for data downlink. This way multiple satellite companies could use the same **interface** for ground-station-as-a-service. So no need to build ground stations.

Pros:

- Low latency (from hours to minutes because ground-station is distributed)
- Better utilization (transmitting every minutes vs every hours)
- More cost-effective (pay as you go v.s. millions to build ground stations)
- Robust

3 Future directions

- Direct-to-cell connectivity: from large disks, to smaller ones like starlink, to allowing phones to directly connect to satellites. Problems: medium access with millions of phones; doppler shifts with fast-moving satellites; hand-overs (much more frequent hand-overs than cell towers).
- Computing in space