From 5G to 6G: Has the Time for Modern Random Access Come?

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Outline

1 5G and IoT Traffic
2 Inefficiencies of Classic Communication Solutions
3 Modern Random Access
4 Modern Random Access for Beyond 5G
5G use cases

- **Enhanced Mobile Broadband**: Gigabytes in a second, 3D video, UHD screens, Work and play in the cloud.
- **Future IMT**: Gigabytes in a second, 3D video, UHD screens, Work and play in the cloud.
- **Massive Machine Type Communications**: Gigabytes in a second, 3D video, UHD screens, Work and play in the cloud.

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**Massive Machine Type Communications**
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5G mMTC and URLLC requirements

- Massive machine type communications (mMTC) target huge and very dense transmitter populations
  - > 10k transmitters per base station
  - > 1M transmitters per square kilometer.
  - push for very high throughput/spectral efficiency.

- Ultra reliable low latency communications (URLLC) collect all use cases where very high reliability and/or low latency is required
  - transmission success > 99.999%
  - latency as low as 1 ms.
  - push for very low packet error rate.
IoT traffic characteristics
A change of perspective

- Transmitters generate **small data** packets
- in a **sporadic** and sometimes unpredictable manner.
- The data channel is shared among a **vast population**.

Key issue: **identify an efficient and flexible policy for the medium access.**
Scheduled access
How overhead becomes an issue

- Scheduled access, e.g. TDMA, is efficient when single transmitters generate (sufficiently) large data packets in a predictable fashion.
- It normally requires a central entity to assign orthogonal resources to the transmitters, i.e. avoiding interference.
- When the data traffic is sporadic, the assignment has to be updated more frequently.
- When the data traffic features small data, the amount of overhead required to update the schedule becomes comparable to the data traffic.\(^1\)

Key issue: overhead limits the efficiency of scheduled access in IoT scenarios.

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Random access
Current approaches

- **Random access** appears as a *natural solution* for shared medium access
  - nodes transmit in an uncoordinated fashion
  - grant-free access: no overhead for resource allocation

- LTE and 5G already resort to random access for logon and resource requests procedures (PRACH)
  - with early data transmission (EDT), possibility to piggyback data.

- Commercial IoT solutions, e.g. LoRaWAN and Sigfox implement variations of ALOHA.

- Interest in using random access for data transmission, yet *performance* of traditional schemes *does not meet mMTC nor URLLC requirements.*
Random access (for data transmission)
Low reliability and low throughput

Key issue: low reliability and low throughput.
Modern random access
A second youth for ALOHA

- The key idea of modern random access is to constructively embrace interference.
- Transmitters send multiple copies of their packets.
- At the receiver successive interference cancellation (SIC) is performed.
- First example was contention resolution diversity slotted ALOHA (CRDSA).²
- Extended by the coded slotted ALOHA (CSA) protocols.³

Transmissions according to CSA

- Transmissions are organized into frames composed by a fixed number of time slots.
- Users becoming active in a given frame, will transmit in the subsequent.
- User 1 transmits two replicas.
- User 2 transmits three replicas.
- User 3 transmits two replicas.
- User 4 transmits three replicas.
**SIC in CSA**

- The receiver buffers the whole frame and starts decoding by looking for interference-free packets.

- User 3 second replica is free from interference and is decoded first.

- Its interference and the interference of its twin is removed.

- Freeing from interference user 2 second replica.

- Iterating the process, we are able to retrieve all data packets.
Performance of CSA

![Graph showing the performance of CSA, ALOHA, and slotted ALOHA in relation to channel load.]
Variations of modern random access

- Enhanced spread spectrum ALOHA,

- Frameless ALOHA,

- Frame-asynchronous CSA,

- Enhanced contention resolution ALOHA.

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Modern random access for beyond 5G

Potential

- Modern random access can bring important performance gains for IoT.

- CSA and other modern random access protocols are already included in satellite communication standards.
  - ETSI DVB-RCS2 (satellite return link standard)
  - S-MIM (S-band mobile interactive multimedia standard).

- Current LTE and 5G solutions not relying on random access for data transmission.

- Modern random access can help fulfill mMTC and URLLC requirements beyond 5G.
Modern random access for beyond 5G

Challenges

- Synergies and interactions with 5G techniques, e.g. OFDM, massive MIMO, NOMA, ..., still unexplored.

- Specific traffic patterns of industrial IoT have to be considered
  - e.g. (partial) correlation among transmitter activity.

- Terrestrial channel characteristics have to be included in the medium access design.

- Combinations of modern random access and NB-IoT shall be considered.
Thank you for your attention!