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Slotted Aloha-NOMA (SAN) in 5G IoT Networks

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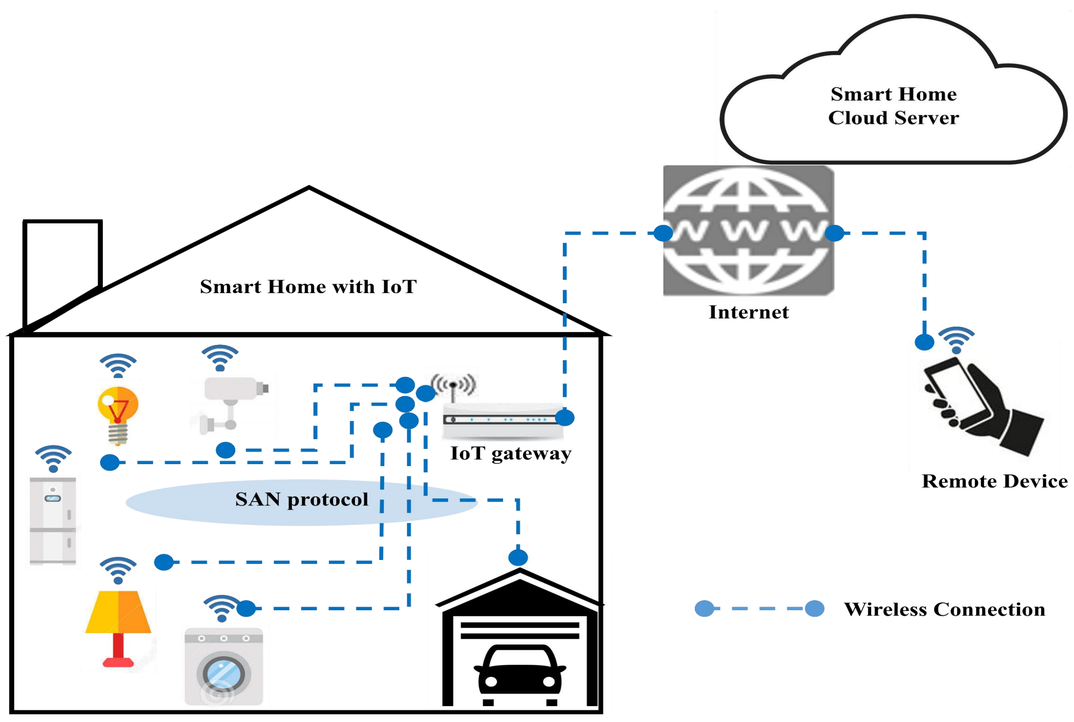
Abstract

Slotted Aloha-NOMA (SAN) is a novel protocol that synergistically integrates the Slotted Aloha (SA) protocol, power-domain NOMA, a novel "random" modulation technique, and a SIC receiver to produce a scalable, easy to implement, energy efficient protocol that significantly improves the throughput performance of IoT devices.

Motivation

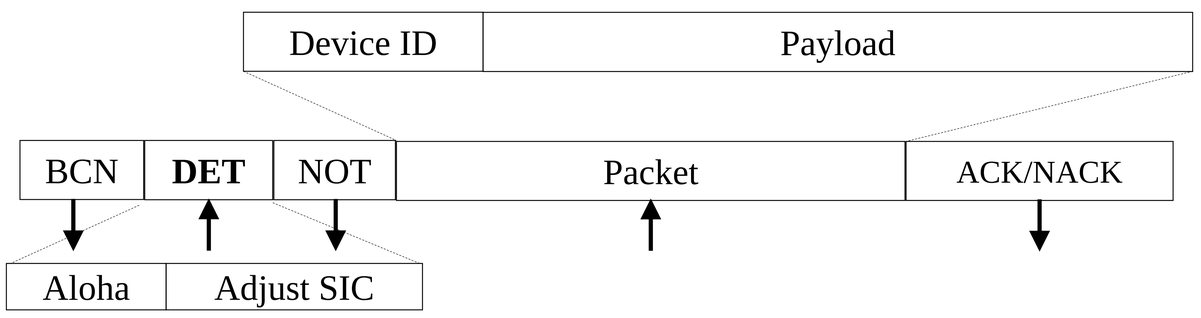
- Connecting large numbers of low-complexity IoT devices over a shared wireless medium via a gateway without any human intervention is an important practical objective.
- To conform to the low-complexity of IoT devices a new medium access control (MAC) protocol is required.



IoT: Anytime, anything anywhere control !

Slotted Aloha-NOMA (SAN)

- **SAN Frame Structure**



BCN: Beacon signal.
DET: Detecting the number of active IoT devices.
NOT: Notification broadcast (number of active IoT devices / abort transmission).
ACK / NACK: Acknowledgment / Negative-Acknowledgement.

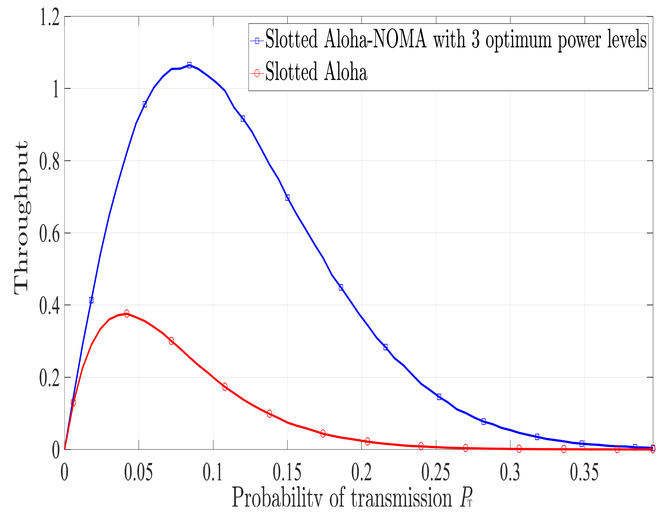
↓: from IoT gateway to IoT devices. ↑: from IoT device to IoT gateway.

- ***Research Challenge***: For NOMA/SIC to work, the active IoT devices must select distinct power levels. This is done in distributed non-cooperative network, where the number and the identity of the active IoT devices is not known at the IoT gateway.
- Multiple hypothesis testing detects the number of active IoT devices.
- Knowing the number of active IoT devices is essential in order to optimize the SIC power levels to distinguish between signals from different IoT devices transmitted on the same time and frequency.
- Each active IoT device randomly picks one of the optimum power levels.

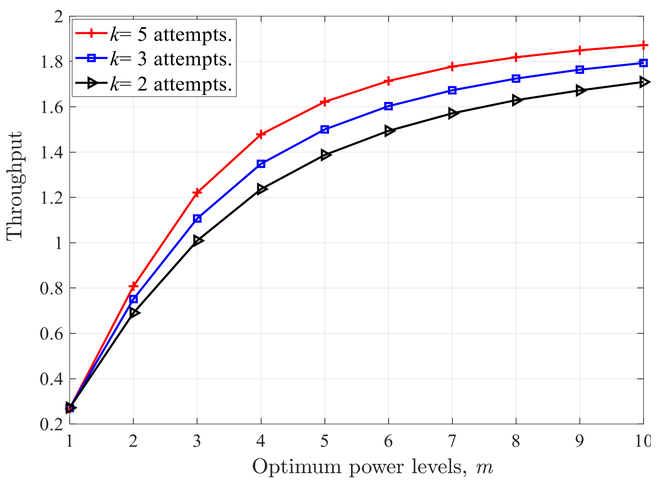
$$P_{success} = \frac{m!}{m^m}$$

$$P(\textit{selecting distinct power levels in } k \textit{ attempts}) = \binom{k}{1} P_{success}(1 - P_{success})^{k-1}$$

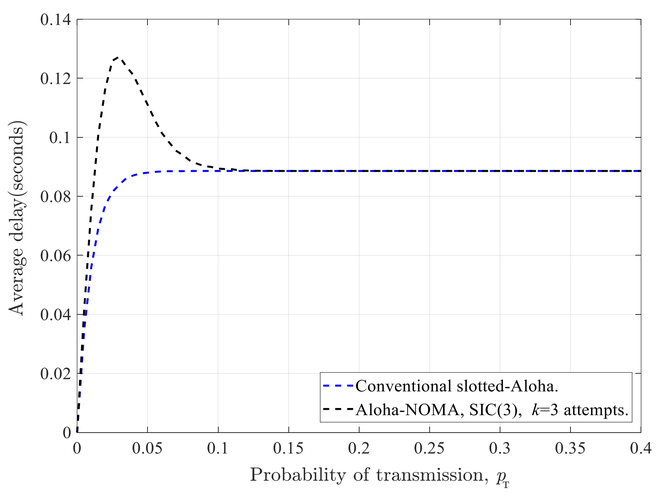
Results



- SAN **significantly increases the throughput** (max of **1.05)** compared with 0.36 for Slotted Aloha when using a SIC receiver with **3** optimum power level for a total number of **60** IoT devices.



- Throughput of SAN increases with the increase of SIC receiver optimum power levels, at the cost of increasingly high transmit power of IoT devices.
- Throughput of SAN increases as the number of attempts for selecting optimum power levels increases, at the cost of increased delay.



- At low probability of transmission the SAN protocol has a larger average channel access delay compared with conventional slotted-Aloha protocol.
- At a high probability of transmission both SAN and SA deliver the same average channel access delay.

Summary

- SAN protocol:
  - ✓ Easy to implement
  - ✓ Scalable
  - ✓ Energy efficient
  - ✓ Compatible with low power/complexity of IoT devices
  - ✓ Significantly improves the throughput
- SAN exploits the simplicity of slotted Aloha and the superior throughput of NOMA with SIC reception.
- SAN uses multiple hypothesis testing in determining the number of active IoT devices.
- Novel "random modulation" algorithm used to select NOMA power levels.

References

- M. Elkourdi, A. Mazin, E. Balevi, and R. D. Gitlin,"Enabling Aloha-NOMA for massive M2M communication in IoT networks," in 2018 IEEE 19th Wireless and Microwave Technology Conference (WAMICON), April 2018.
- E. Balevi, F. Al Rabee, and R. D. Gitlin, "ALOHA-NOMA for massive machine-to-machine IoT communication," in 2018 IEEE International Conference on Communications (ICC), May 2018.