Energy Efficient Wireless Systems and Sustainability

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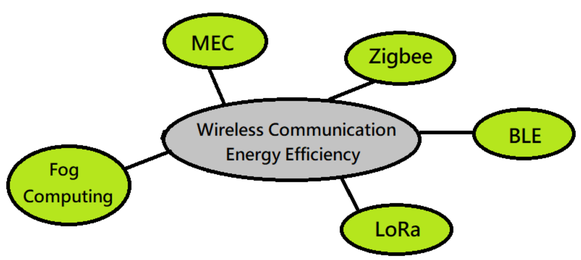
Introduction

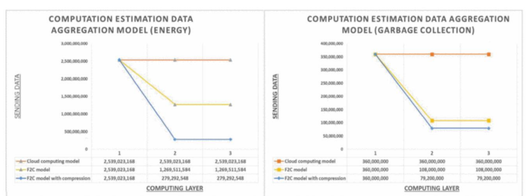
- To provide information on energy efficient concepts and approaches to aid in the design of wireless products with reduced carbon footprint and improved sustainability.
- Deliverables consist of a Final Report, Excel spreadsheet with key references, and visualization of the examined papers and their interconnections with the web of approaches.
- Study papers including multiple topics on energy efficiency on communication
- Topics include ZigBee, BLE, LoRa, fog computing and some other topics
- Find similarities between papers



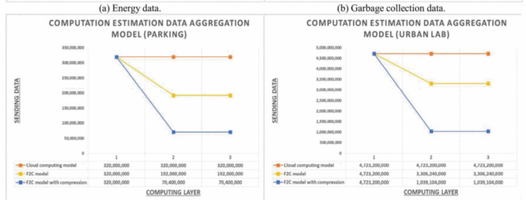
Fog Computing

Fog Computing:
- Latency Reduction
- Increased Security
- Overall Increase In Speed and Efficiency
- Enhanced Services for Remote Locations
- Improved Response Time
- Reduced Cost Of Bandwidth

Real-World Applications:
- Connected cars
- Smart grids and smart cities
- Smart Parking
- Smart Home
- Healthcare Activity Tracking



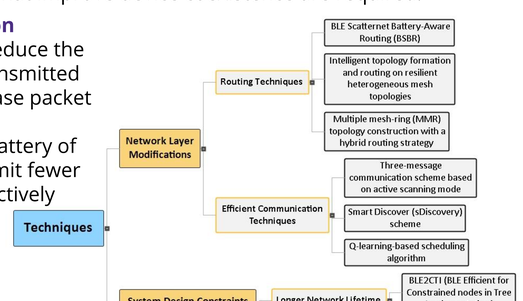
(a) Energy data. (b) Garbage collection data.



(c) Parking data. (d) Urban Lab data.

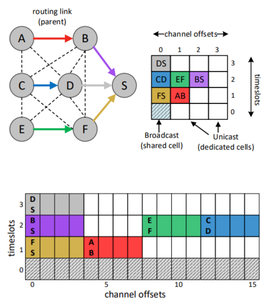
Bluetooth Low Energy (BLE)

- **BLE:** Intended to provide considerably reduced power consumption and cost while maintaining a similar communication range as Bluetooth.
- **Network layer modifications**: Dynamic source routing schemes that increases network lifetime by over 15% while increasing throughput performance by up to 50% compared to a traditional BLE-based MANET routing algorithm.
- As the BLE devices compete for access to spectrum, collisions are inevitable and methods that improve device coexistence are required.
- **Efficient communication schemes:** Significantly reduce the number of messages transmitted by each node and decrease packet loss ratio.
- **Benefit:** Preserves the battery of BLE nodes as they transmit fewer radio messages and effectively spent less time actively communicating.



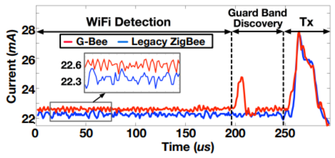
ZigBee/IEEE 802.15.4

Time Slotted Channel Hopping:
- Part of MAC layer of IEEE 802.15.4 standard.
- Aims to improve network reliability by communicating in alternating channels and times.
- Uses simple blind hopping: all 16 available channels in 2.4GHz band selected -> all transmissions share same interference



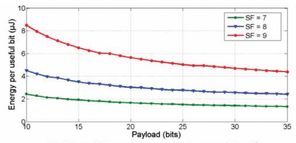
MAC Layer Modification: MABO-TSCH
- Utilizes blacklisting and selective channel hopping to improve performance in high interference environments
- 3 algorithms: Channel Offset Assignment, Distributed Blacklist Negotiation, and Multi-armed Bandit Link Estimation
- Improves reliability by 50-90% compared to default TSCH

PHY Layer Modification: Wi-Fi Guard Band for Safeguarded ZigBee, G-Bee
- Avoids cross-technology interference (CTI) by using guard band of Wi-Fi to incorporate ZigBee signal
- For a 30-byte packet transmission, G-Bee consumes 83% less energy than legacy ZigBee

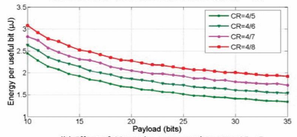


LoRa

LoRa:
- A promising platform for connecting large scale of Internet of Things (IoT) devices
- Provides low-power long-range communication with a low data rate
- Two fundamental variables: spreading factor (SF) and data rate (DR)
- Motivation: Energy consumption almost doubles as SF increases by 1

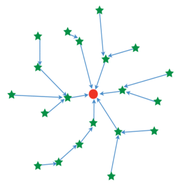


(a) Effect of SF on the consumed energy, CR = 4/5



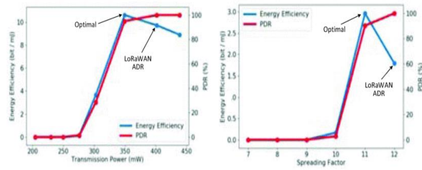
(b) Effect of CR on the consumed energy, SF = 7

Energy efficient scheme:
- Adjust SF and DR dynamically to maximize energy efficiency
- Use multi-hopping (tree-structure) to avoid long distance communication
- Gateway planning



Tree Network

Star Network



a) Impact of transmission power.

b) Impact of spreading factor.

Connecting the Research

- Individual areas of research were combined to create a Bibliographic Network Visualization using Web of Science, Kumu.io, and Google Colab
- Two visualizations: citations (papers from present to future) and references (papers from past to present)

Future Work

- Take theoretical LoRa energy efficient algorithms into practice
- Apply energy saving technique to simulation and real-world prototype
- Propose a new modification to existing communication protocol based on previous research
- Continue literature search of sources with high indegree in network visualization

References

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