A Novel IEEE 802.11 Power Save Mechanism for Energy Harvesting Motivated Networks

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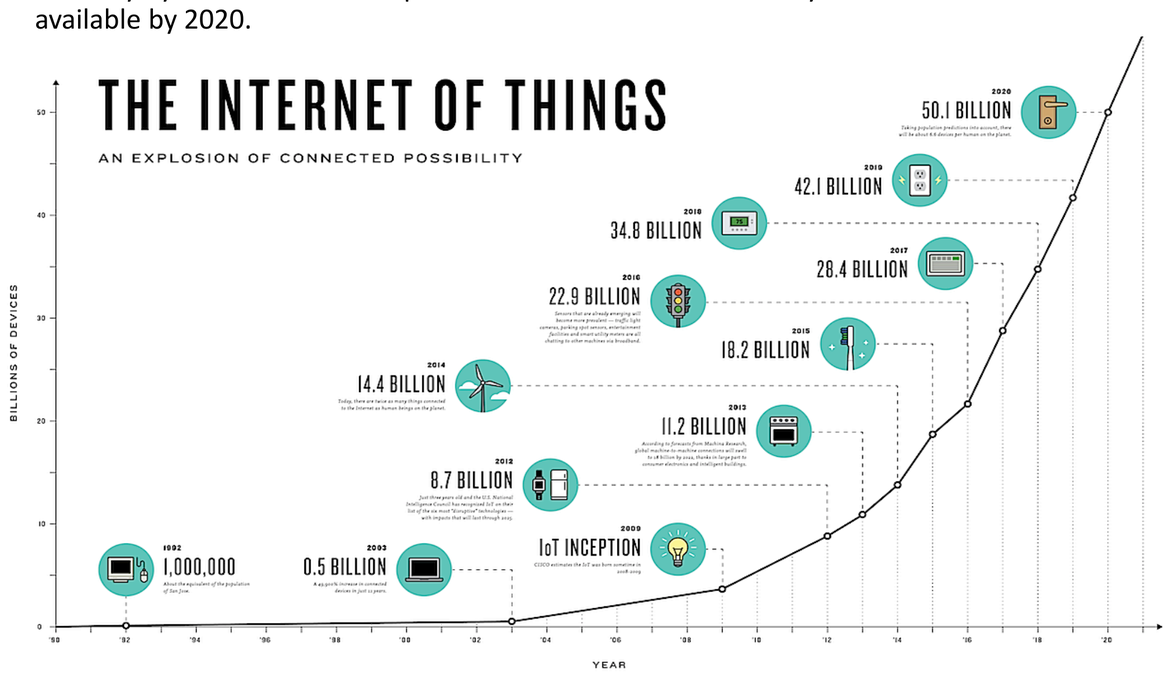
ABSTRACT

The spread of wirelessly connected computing sensors and devices and hybrid networks are leading to the emergence of an Internet of Things (IoT), where a myriad of multi-scale sensors and devices are seamlessly blended for ubiquitous computing and communication. However, the communication operations of wireless devices are often limited by the size and lifetime of the batteries because of the portability and mobility. To reduce energy consumption during wireless communication, the IEEE 802.11 standard specifies a power management scheme, called Power Saving Mechanism (PSM), for IEEE 802.11 devices. However, the PSM of IEEE 802.11 was originally designed for battery-supported devices in single-hop Wireless Local Area Networks (WLANs), and it does not consider devices that equip with rechargeable batteries and energy harvesting capability. In this thesis, the original PSM is extended by incorporating with intermittent energy harvesting in the IEEE 802.11 Medium Access Control (MAC) layer specification, and a novel energy harvesting aware power saving mechanism, called *EH-PSM*, is proposed. The basic idea of EH-PSM is that a longer contention window is assigned to a device in energy harvesting mode than that of a device in normal mode to make the latter access the wireless medium earlier and quicker. In addition, the device in energy harvesting mode stays active as far as it harvests energy and updates the access point of its harvesting mode to enable itself to be ready for receiving and sending packets or overhearing any on-going communication. The proposed scheme is evaluated through extensive simulation experiments using OMNeT++ and its performance is compared with the original PSM. The simulation results indicate that the proposed scheme can not only improve the packet delivery ratio and throughput but also reduce the packet delivery latency.

INTRODUCTION

Internet of Things (IoT)

- The spread of wirelessly connected computing sensors and devices and hybrid networks are leading to the emergence of an Internet of Things (IoT), where a myriad of multi-scale sensors and devices are seamlessly blended for ubiquitous computing and communication.
- IoT applications have the potential to create economic impact of $2.7 trillion to $6.2 trillion annually by 2025 and it is also predicted that 30 billion wirelessly connected devices will be available by 2020.



Problem

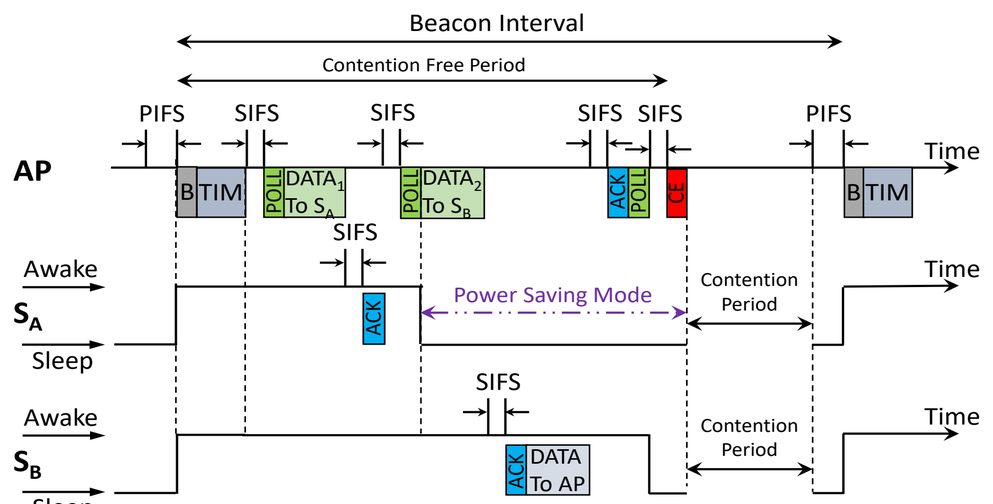
- The limited lifetime of the battery to power wireless devices must be overcome.

Energy Harvesting Networks

- Equipped with energy harvesting devices
- Energy harvesting from an immediate environment
  - Sunlight (Solar)
  - Heat (Thermal)
  - Motion or vibration (Kinetic)

IEEE 802.11 POWER SAVE MECHANISM

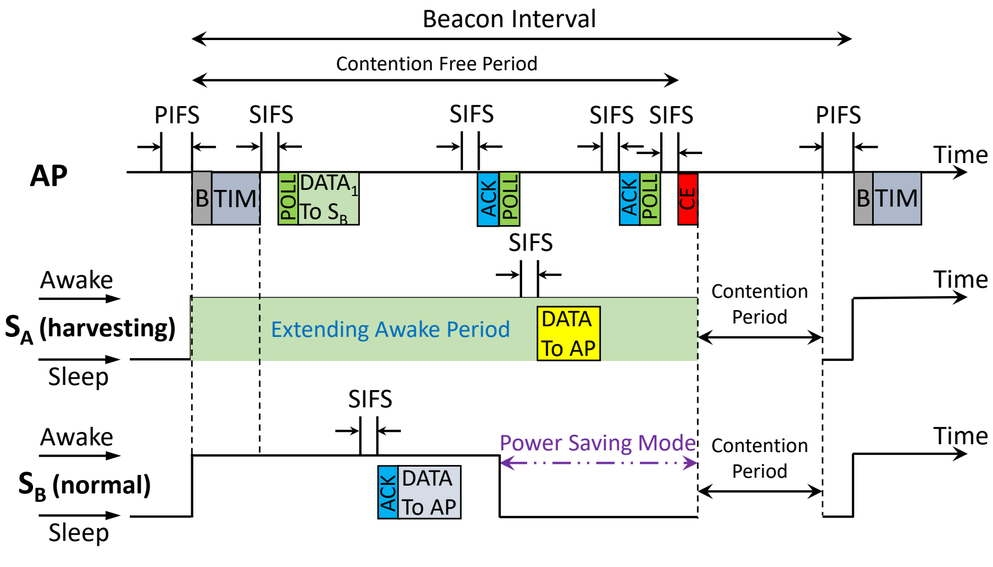
- The devices sleep most of the time (low power state)
- Periodically wake up to receive the packets buffered at access point (AP) (high power state)



ENERGY HARVESTING POWER SAVE MECHANISM

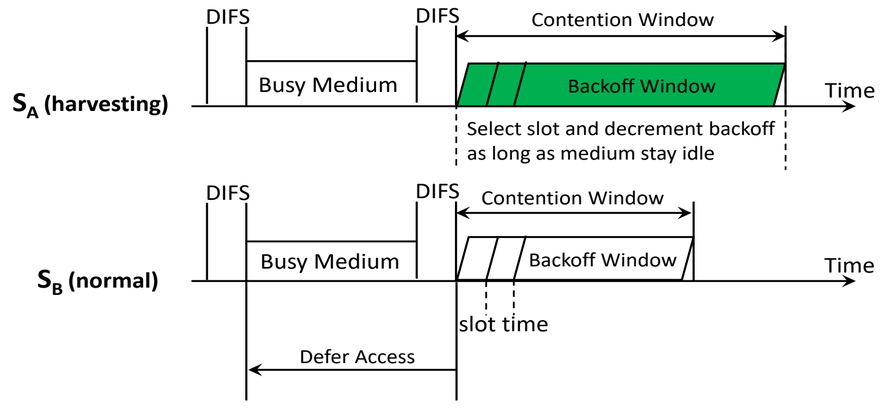
EH-PSM with Extended Awake Time Period

- Devices in energy harvesting mode stay awake as far as they harvest energy
- Otherwise, they follow original PSM

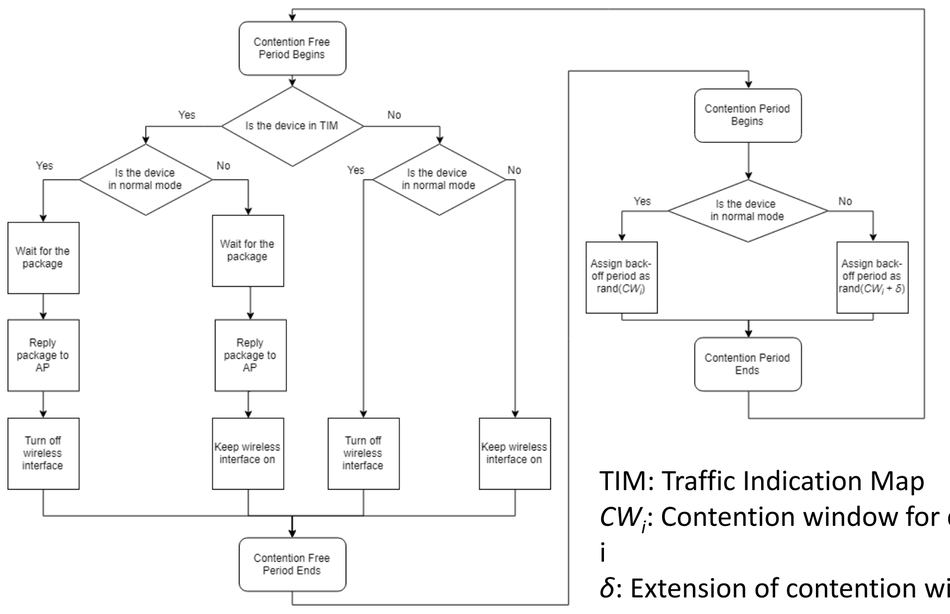


Assigning Contention Window in EH-PSM

- Assign a longer contention window to a device in energy harvesting mode
- Thus, the device in normal mode which is possibly containing less amount of residual energy has more chances to access the medium earlier and quicker.



Flowchart of EH-PSM

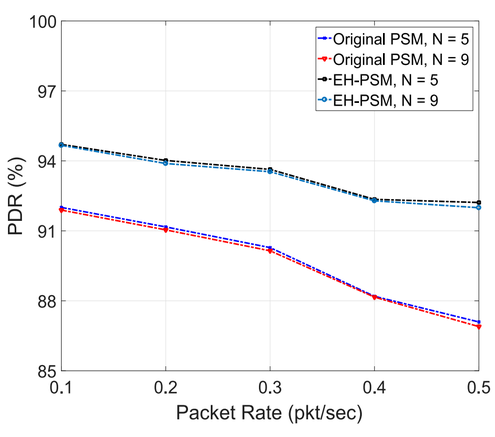


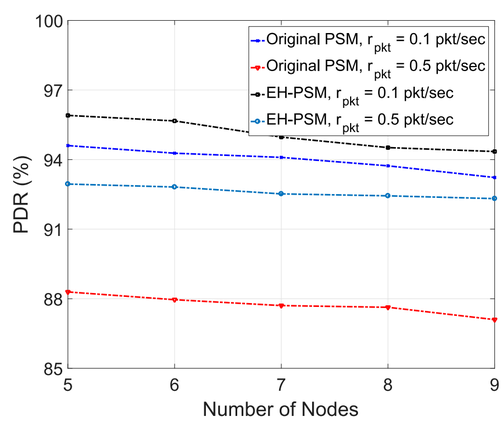
TIM: Traffic Indication Map
CW_i: Contention window for device i
δ: Extension of contention window

PERFORMANCE EVALUATION

Packet Delivery Ratio (PDR)

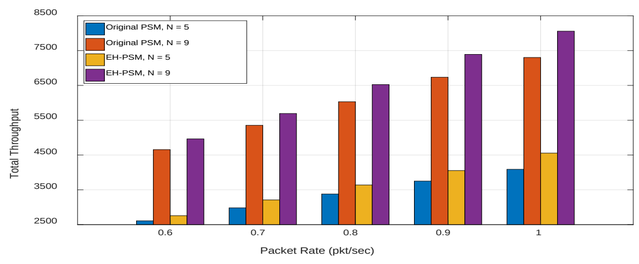
- PDR is the ratio between the received packets by destination and the generated packets by the source

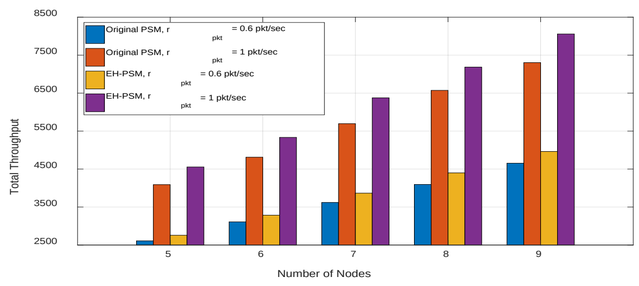




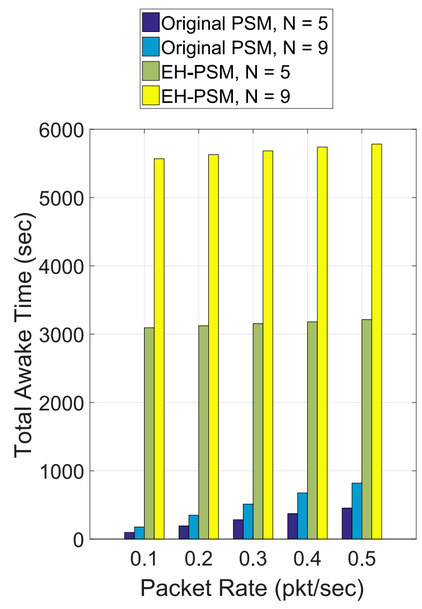
Throughput

- Throughput is number of packets that are successfully sent



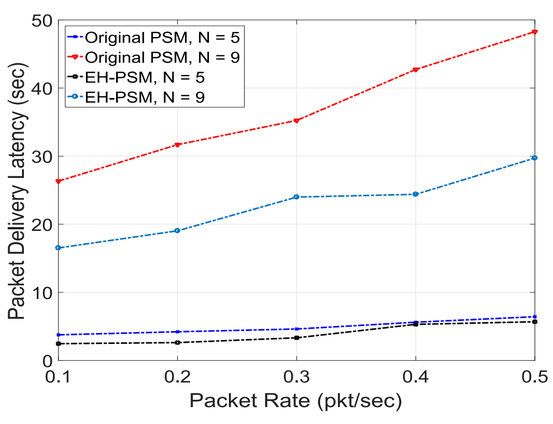


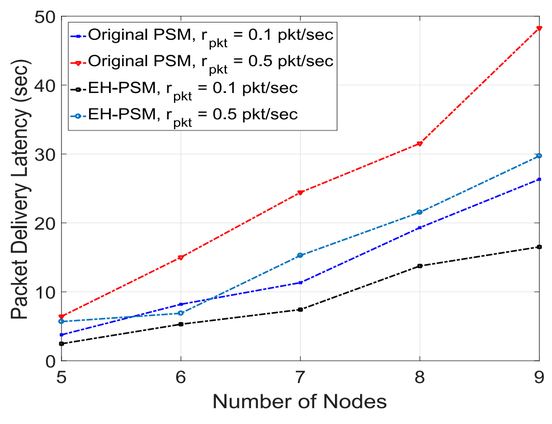
Total Active Time



Packet Delivery Latency

- Packet delivery latency occurs when the device in normal mode switches to power save mode after receiving all buffered packets from the AP and new packets are generated. So new buffered packets have to wait until the next beacon period and latency observed.





CONCLUSION

The IEEE 802.11 Medium Access Control (MAC) layer specification was investigated. A novel energy harvesting aware power saving mechanism, called EH-PSM, was proposed. Basic idea of EH-PSM Assigning a longer contention window to a device in energy harvesting mode than that of a device in normal mode to make the latter access the medium earlier and quicker. Moreover, during harvesting period, the device stays awake to receive and send packets, or overhear any on-going communication. The performance of the proposed scheme was evaluated and compared with the original PSM of IEEE 802.11. The simulation results indicate that the proposed scheme achieves better performance in terms of packet delivery ratio, throughput and packet delivery latency.