Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [MAC Concepts for IEEE802.15.6]
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Re: [Informational contribution to IEEE802.15.6.]

Abstract: [Informational contribution of emergency management concepts for IEEE802.15.6 Body Area Networks (BANs). The suggested solutions apply to both medical BANs (MBAN) and non-medical BANs.]

Purpose: [This Informational contribution introduces issues and basic concepts for the management of both medical and non-medical emergency situations in BANs.]

MAC Concepts for IEEE802.15.6

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- Elements of the Emergency Management Framework
  - Adaptive Channel Access
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TG6 Requirements Targeted

- Section 8 of the Technical Requirements, 15-08-0644-09-0006-tg6, mandates Emergency Management capabilities for the IEEE802.15.6 specification.
  - Emergency Management
    - MUST support alarm state notification across BAN in less than 1 second
    - MUST provide prioritisation mechanisms for emergency traffic and notification
  - Power management
    - Should provide a mechanism to lower the priority of or cancel power management in emergencies.
    - Power management (e.g. using duty cycling) should be provided whilst not impacting latency requirements.

Channel Access

Motivation for Adaptive Channel Access Mode

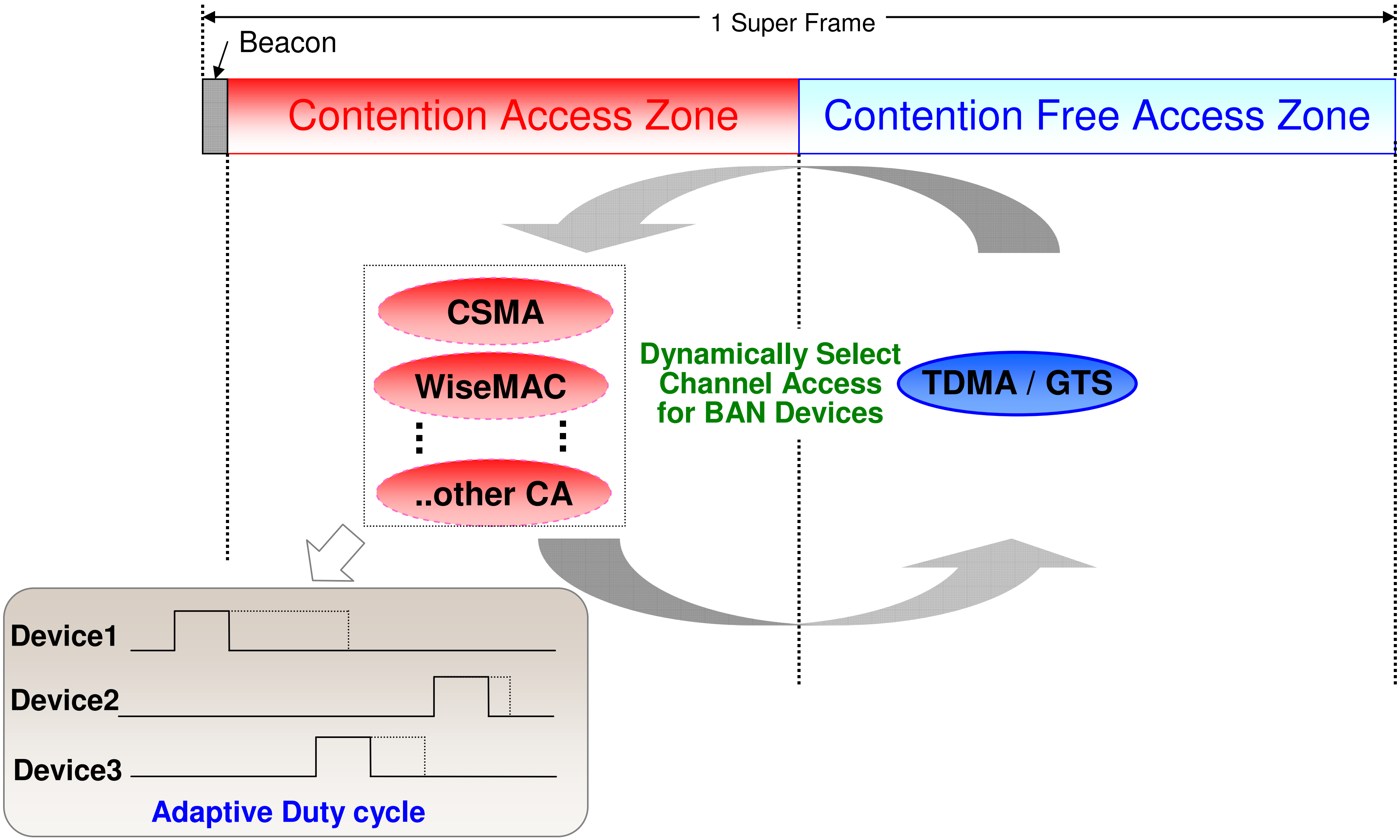
To prolong battery life of wireless BAN devices / sensors without compromising latency and QoS of BAN applications (Medical and Non-Medical).

- TDMA/GTS
  - Used when multiple BAN devices are detecting a state of emergency and require reliable data delivery
  - Not as power efficient as WiseMAC due to regular wake ups
- CSMA:
  - Can be used when BAN devices are detecting a state of emergency and require the BAN coordinator to stay awake
  - Not power efficient for the BAN coordinator
- WiseMAC:
  - High power efficiency under normal (non-emergency) conditions
  - Can be used when there is not a state of emergency and BAN devices do not require the BAN coordinator to stay awake

- Individual technique not efficient for all BAN conditions.
- An adaptive or switched channel access mode is more energy efficient without compromising the latency requirements for emergency data traffic
- Access Mode adaptation based: on traffic type, loading and battery energy

Frame Structure (example)

- Based on IEEE802.15.4 and IEEE802.15.3 principles:



Adaptation Criteria (examples)

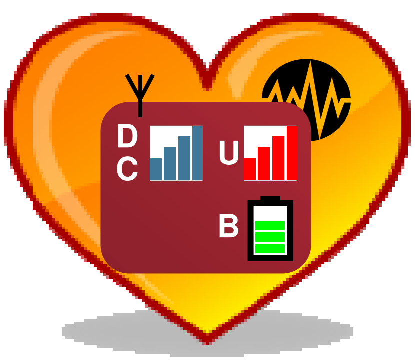
Objective: To prolong battery life of wireless BAN devices / sensors without compromising latency and QoS of BAN applications (Medical and Non-Medical).

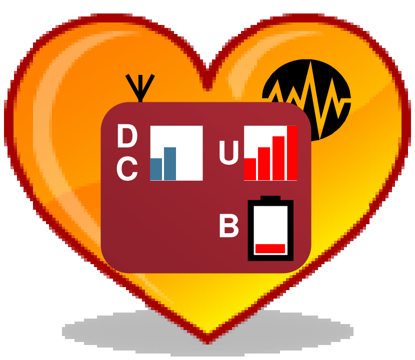
- Traffic Type & Traffic Priority
  - Medical Emergency Alerts/Alarms,
  - Medical Priority → one or more priority levels
  - Vital life parameters/data in normal state (non-emergency)
  - Non-medical BAN traffic delay sensitive
  - No medical, delay tolerant
  - etc..
- Measurement cycles
  - How often data is measured/collected
  - How often data needs to be transported to/from the coordinator
- Traffic Loading
  - Total traffic load
  - Amount and delay statistics of the Emergency traffic
  - QoS
- Battery Energy Status
  - Remaining battery energy level
  - Applications that adapt in accordance with energy remaining in the battery

Sleep Cycle Management

Sleep Cycle Adaptation

- BAN device sleep cycle adapted to different levels of emergencies and to different levels of available or remaining battery energy/power.
  - In situations where battery power is low, reduce wake-to-sleep duty cycle maintain minimum monitoring level as long as possible.
  - In situations where battery power is adequate, maintain normal/high level of monitoring & reporting.





Emergency State Induced Sleep Cycle Adaptation (example)

- Based on level and/or nature of emergency

Escalating Urgency

Urgency Index	Example Urgency Level	Example Duty Cycles
0	Device detecting normal condition	**Low Wakeup:** Longest sleep time, very low duty cycle
1	Device detecting slightly abnormal condition	**Medium Wakeup:** Slight increase of duty cycle
2	Device detecting abnormal condition	**High Wakeup:** Increase of duty cycle
3	Device detecting emergency	**Continuous :** Dramatic increase of duty cycle or continuous wake mode

Battery State dependent Sleep Cycle Adaptation (example)

Battery Status Index	Example Battery Level	Example Duty Cycles Rule Table			
		Low Wakeup	Medium Wakeup	High Wakeup	Continuous Wakeup
0	0%-25%	✓	×	×	×
1	25%-50%	✓	✓	×	×
2	50%-75%	✓	✓	✓	×
3	75%-100%	✓	✓	✓	✓

Emergency Management & Prioritisation

TG6 Requirements Relating to Emergency Capabilities

- Section 8 of the Technical Requirements, 15-08-0644-09-0006-tg6, mandates Emergency Management capabilities for the IEEE802.15.6 specification.
  - Emergency Management
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Emergency State Notification

Whom / which entity to notify and its purpose

- To notify application system/software
  → for taking appropriate action at application level

- To notify medical staff
  → for taking appropriate action by the medical staff

- To notify the BAN and nodes
  → to manage the priority within the wireless comms network

- Other…..

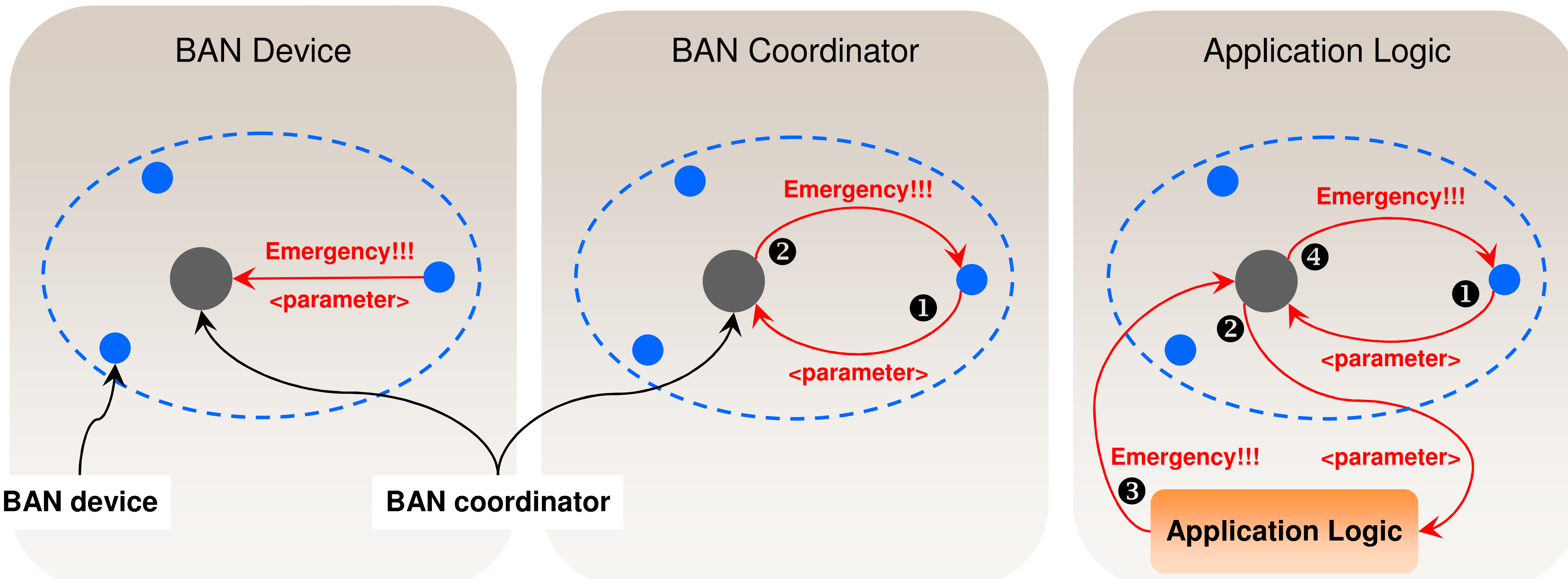
Within the scope of IEEE802.15.6 spec

Emergency State Notification

- To notify BAN and BAN nodes to manage the priority within the wireless communications network

A two step approach :-

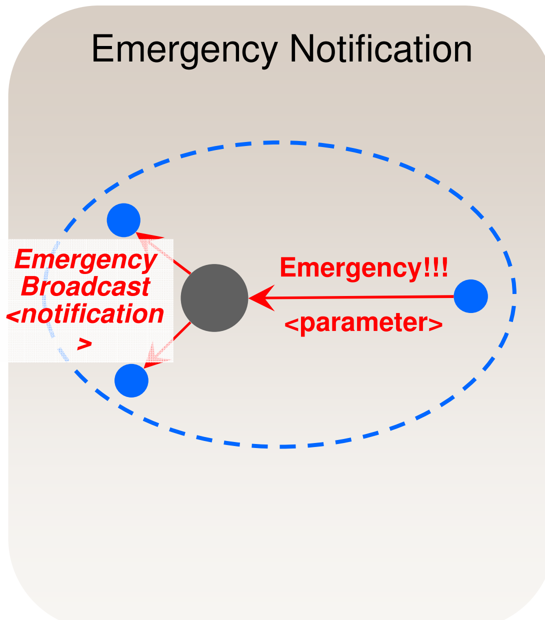
- Step 1: Emergency state notification of BAN devices to BAN coordinator
  - Emergency state detection can be made by:



- Needs to have ACK/NACK feedback to ensure that the Notification is successfully received

Emergency State Notification

- Step 2: Broadcast emergency notification by BAN coordinator to other devices within the BAN.



- TCP latency can be a serious problem
- A fast wake-up, synchronisation and signalling is needed to meet the 1 second requirement.

Emergency Traffic Prioritisation

- In order to minimise latency of emergency data traffic prioritise, we need to consider
  - channel access & resource allocation,
  - transmission of data packets and
  - ACK/NACK signalling

- Each node Sensor Device, Coordinator, Relay Node etc, must be able to identify emergency data traffic

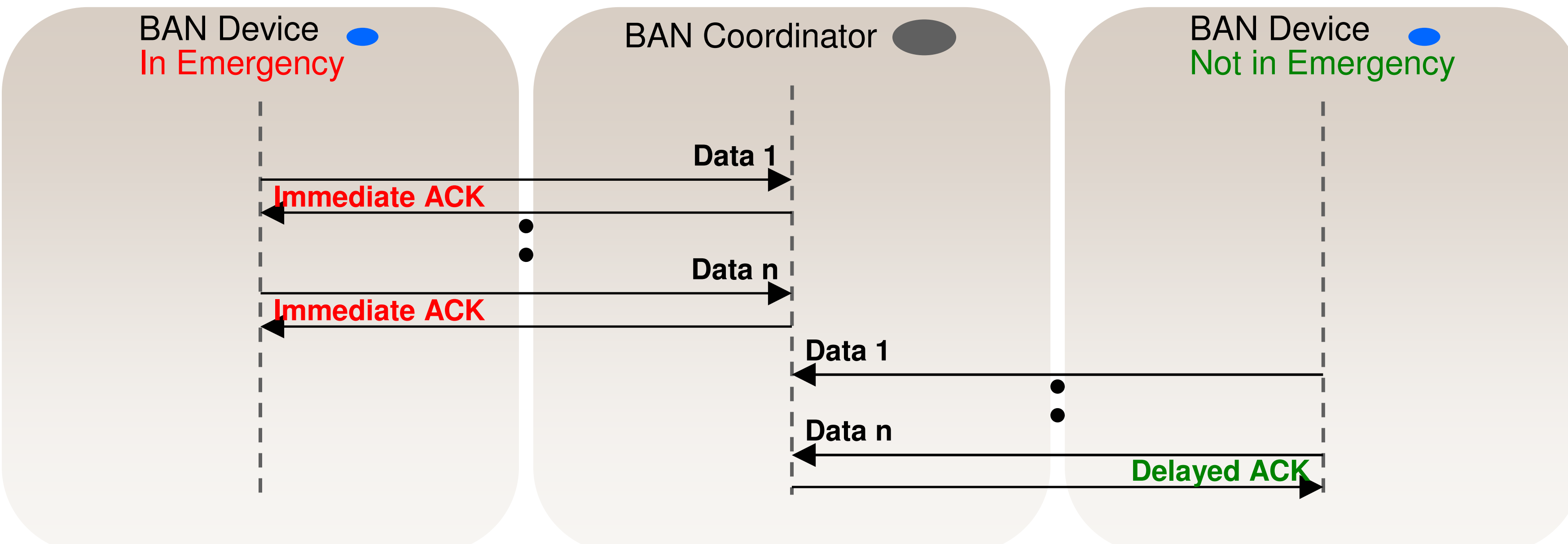
  → to provide prioritised/low latency channel access & resource allocation

- Need to identify / tag emergency data traffic

- To prioritise ACK/NACK responses of emergency data packets (non-streaming and streaming)

Prioritised ACK/NACK Signalling

- Can be based on IEEE802.15.4 and 802.15.3 approach:-
  - Delayed ACKs used for non-emergency data acknowledgements
  - Immediate ACKs used for:
    - For emergency data acknowledgements
    - For prioritisation of the acknowledgement when a BAN device is in a state of emergency and requires fast ACKs to reduce delay



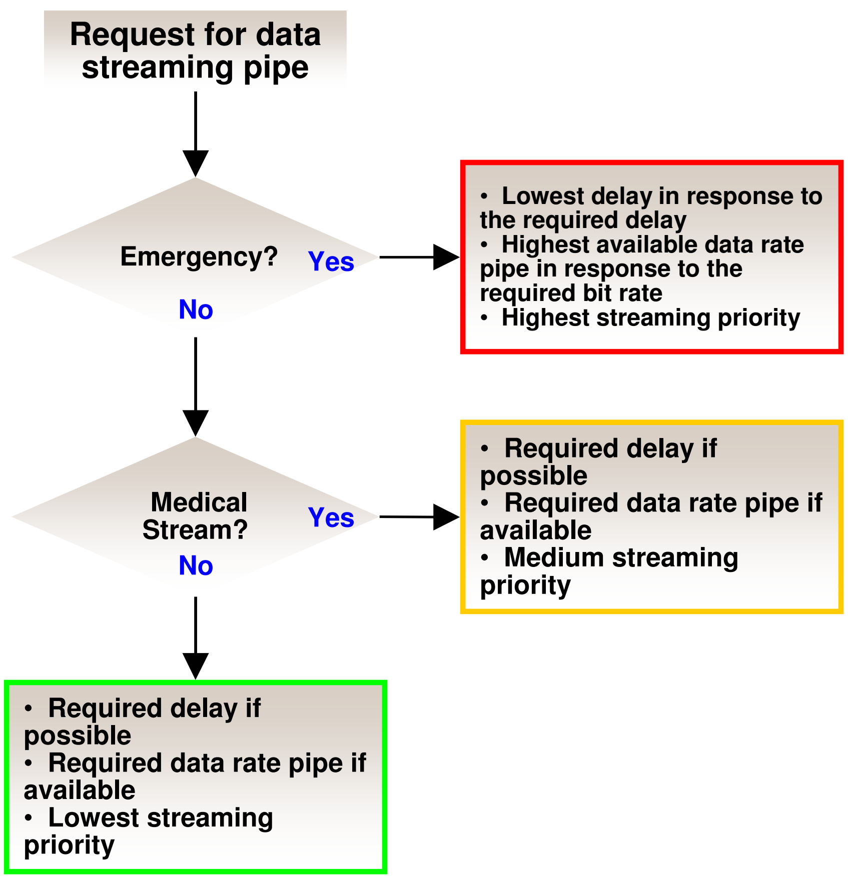
ACK Policy (Example)

Ack. Type	Description
0	No Ack.
1	Ack.
2	Delayed Ack.
3	Immediate Ack.

Data Streaming with Emergency Prioritisation

- To enable Scheduling prioritisation for data streaming traffic
  - Stream indexing to indicate priority
    - Eg: 1 Octet stream index range can be divided into priority levels
  - Medical applications such as ECG, EEG and medical video may get higher streaming priority in emergencies

Emergency Induced Data Stream Scheduling



Summary

- Adaptive channel access mode, dependent on emergency state and on traffic loading is recommended for ensuring high channel availability for emergency data traffic and high energy efficiency for non-emergency conditions/devices.
- Adaptive sleep cycle, dependent on battery energy remaining is recommended for ensuring high energy efficiency whilst suitably meeting the needs of medical monitoring.
- In order to meet requirements of the low latency Emergency state notification/management, Priority Management and QoS Management, a new MAC Layer *emergency framework* is recommended for IEEE802.15.6