Context aware methods for uplink centric Narrow Band IoT Devices

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***Abstract*—Cellular communication is a great enabler for Internet of Things (IoT), as it offers coverage, quality of service and most importantly the maintenance and operations is centralized and taken care by the operator. Narrowband IoT (NB-IoT) is designed by 3rd Generation Partnership Project (3GPP) for a plethora of use cases which cater to broad spectrum of capabilities but introduces few in-efficiencies in the resource allocation and adds overhead in the system. We envisage a use case aware NB-IoT network, which creates opportunities in the system for dynamic adaptation of the resource allocation for NB-IoT devices. We present protocols and algorithms both on the network and device side suitable particularly for 3GPP NB-IoT deployment. This demonstrates over 90% improvement in the power consumption (through removal of DRX and measurements), lowers RACH (access) overhead during device admission (through context based cell search), shows 80% improvement in the resource allocation (through group based SPS allocation), and improvement in reliability during emergency scenario. Thus, enabling use cases for activity tracking and emergency reporting within the latency budgets, improving user experience and battery life for NB-IoT devices in the field.**

Keywords—NB-IoT, Context Based Search, Context-Aware, Emergency IoT, wearables

I. INTRODUCTION

Narrowband Internet of Things (NB-IoT) offers a wide range of features and is a huge opportunity for cellular network, which already offers ubiquitous coverage, and applies self-optimizations. NB-IoT enables three major use cases [1]

- High latency ~upto 10seconds
- Low latency 1.6-3seconds.
- Keep alive or latency tolerant.

A generic design [4] [5] often leaves sub optimal choices for a specific use case. In proposed scheme, we have considered possible design changes; by relooking the NB-IoT device from use case perspective, as unlike mobile devices, their deployment solves only a specific problem. Currently NB-IoT Network does not differentiate devices based on latency. The 3GPP solution for NB-IoT is generic for 1.6 to 10seconds latency. We propose a solution where NB-IoT network makes decision based on this use case. In this paper we propose novel mechanisms within the NB-IoT protocol architecture

a. Ultra-deep sleep mode in the device
b. Context based cell search
c. Context based scheduling
d. Enhanced SPS scheduling
e. Reliable emergency handling

Through simulation in real test bed, we show that an overall improvement in energy consumption by over 90% and improvement in resource allocation by 80% with our proposed solution.

The rest of paper is organized as follows. Section II analyses the use cases for which we propose the solution. Section III discusses the System Model. Section IV discusses the proposed mechanism with results and gains when applicable. Section V shares the conclusions.

II. DEVICE SPECIFIC USE CASE ANALYSIS

A. Categorization of Uplink centric Use Case

We analyzed the requirements of activity trackers especially for kids and seniors requiring assistance and found that such devices access network based on events generated in the device; broadly classified as 'uplink-only' or mobile-originated. We classified the devices under two major buckets from use case perspective.
(a) "Delay tolerant Mobile originated data", or (use case (iii) – Periodic reports [1])
(b) "Emergency information data", or (use case (ii) – Emergency reported [1])

This created a basis of our proposal of a 'use-case' aware network, and enables optimizations in resource allocation and device behavior bringing in gains for the operator on one hand and for the device/user on the other.

We also observed that these devices/users exhibit a fixed and restricted mobility pattern, i.e. they have some pre-defined places, where they go to as per their regular schedule. Network access from the devices can thus be associated with time, location, or activity.

III. SYSTEM MODEL

Based on the nature of the device, we termed this 'uplink only' device as Machine Type Communication – Mobile Originated (MTC-MO) - only (mobile originated only) device, which has also been explored in [3], however we extend the idea further for context based network selection and, resource allocation and robust emergency handling.

In principal 'MTC-MO-only' relaxes a major part of idle mode and connected mode processing. We estimate our gains based on system model in [4], for a 200KHz cell bandwidth, and iterate over 5K, 10K and 30K MTC devices per cell with 10% resource reservation. MTC devices access the network for 50, 100, 500 or 1500 times within 24 hours.

IV. PROPOSED MECHANISM

A. Ultra deep Sleep

In Idle mode, it is not necessary for the NBIoT device to monitor paging, consequently, there is no need to follow DRX cycle viz. sleep and wake up procedure. Device selects

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a cell, just before uplink operation, thus it does not need to perform measurements/re-selections.

Removal of DRX and cell re-selection enables huge power saving in idle mode as device goes to ultra-deep sleep (much longer then 3GPP Rel13 eDRX) and shuts off its modem/RF/processor as captured in Fig 1. It wakes up again based on the explicit trigger from the sensors or interface (emergency use case or delay torrent). This lowers the bottom-current by almost 90%, and improves the standby battery life to nearly a week for the device as captured in Fig. 2 (based on estimated targets from [7]).

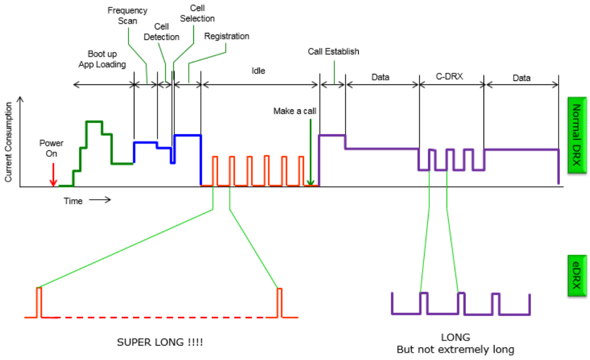

Fig 1. Current consumption with eDRX

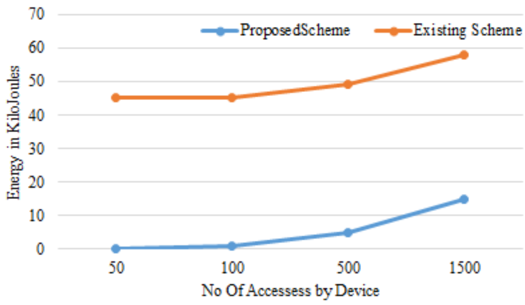

Fig 2. Energy Consumption Versus Number of Accesss for Uplink centric operations (per day)

B. Context Based Cell Search(System Acquisition)

As per use case, the device would most likely be in similar premises (restricted locations during the day), like a home or office, so a network access may happen on a known network every time. The accesses will be profiled based on time or location, and can form a context database on the device, Table1. The context forms on historical acquisition and adapts as the device ages.

Table 1 Device Context Database

Context	Time	Location	Network
#1	T=T1	L=L1	{Cell-1, PLMN-1, RAT-1, TA-1,UL-TxPow-1, PUSCH_pow-1, PUCCH_pow-1 }
#...	….	….	…
#N	T=Tn	L=Ln	{Cell-n, PLMN-n, RAT-n, TA-n,UL-TxPow-n, PUSCH_pow-n, PUCCH_pow-n}

Device should follow two-step search procedure, whenever there is a trigger to access the network

Step-1: Search as per current context

Step-2: If Step-1 fails, fall back to 3GPP behavior for cell search and acquisition

The location can be reference based on serving cell and neighbor cell measurements. As the device would have almost have same path (e.g. Home to Office/School) Fig. 3, the trigger to send Uplink data would map to specific location and thus save unnecessary acquisition on other cells eventually reducing current consumption and increasing battery life.

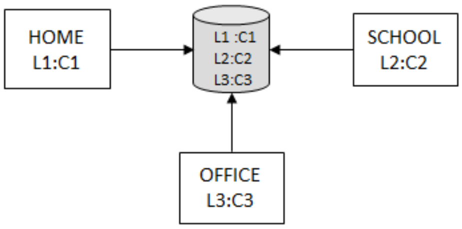

Fig 3. Location Based Cell Search

C. Context based Scheduling

For a Delay tolerant use case, the device can initiate network access, when it calculates that the channel compensation is lowest (thereby saving power), based on sensor information. The channel compensated can be different when it is either (i) Outdoor leading to maximum coverage, or (ii) NW load is relatively load. For example, if the device is static and outdoor it can access the network, as shown in Fig. 4. Network may also configure an appropriate time when the device accesses it, based on traffic loads expected during that time, as shown in Fig. 5.

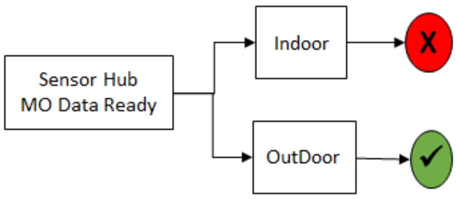

Fig. 4. Tx when Device Outdoor

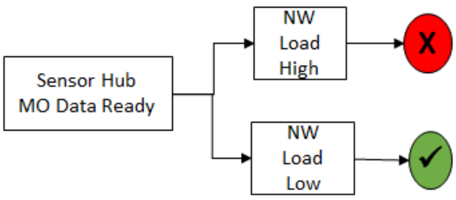

Fig 5. Tx when Low Network Load

D. Enhanced SPS scheduling (Delay tolerant MO data)

Once Step-1 search is successful, based on the context, coarse level information for Timing alignment (TA), and UL transmit power (UL-TxPow, PUSCH_pow, PUCCH_pow), is available. This minimizes the need of random accesses channel (RACH). Pre-allocated resources (SPS) across all MTC-MO-only devices is shared using time domain multiplexing. Devices having similar or integer multiple of scheduling interval will be grouped together.

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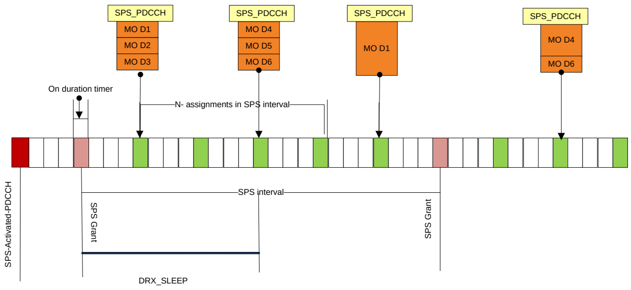

Fig 6. Semi persistence scheduling based resource allocation for a Group of UE's

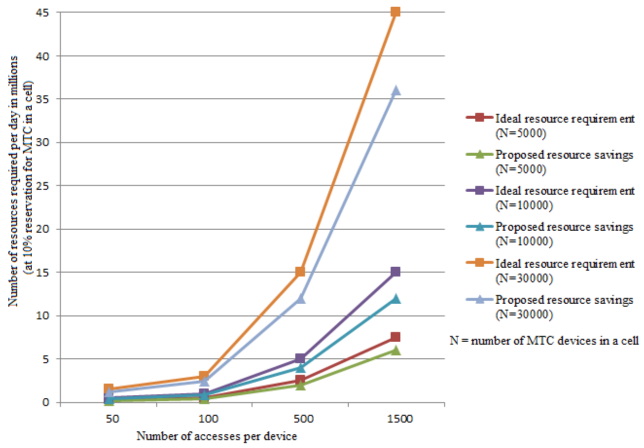

Fig 7. Resource savings in proposed SPS scheme

Fig. 6 shows, SPS_PDCCH at every SPS scheduling period to allocate the resources for the scheduled UEs from within the same group, This optimizes the resource allocation overhead, which gives around 80% gains over traditional SPS allocation captured in Fig. 7.

However, if Step-1 search fails, then 3GPP defined RACH procedure is performed, so that UE can be allocated a new group and corresponding SPS resources at the selected cell, the group or SPS in the previous cell will be released through backhaul signaling.

E. Connected Mode(Emergency Service)

During emergency access the communication is expected to be highly reliable and with minimum latency. We propose to have cross layer optimization, where emergency service would trigger the uplink data with highly reliable radio link entity.

Alternative-1 (Network aware): Logical link entity established for the emergency service indicates to the network of the emergency nature of the service. Thus, network with then allocate the UL resources with maximum redundancy and minimum modulation with additional frequency, time diversity (or coordinated multipoint transmission resources).

Alternative-2 (Network Un-aware): Device minimizes the sounding reference signal power, in order to mimic path loss, which would eventually provide resources with maximum protection and minimum modulation with additional time and frequency diversity (transmission modes).

V. CONCLUSION

3GPP LTE and other cellular IoT proponents optimize their network primarily to satisfy low throughput requirements and leverage the delay insensitive nature of the expected NBIoT traffic. Knowledge of use cases is under-utilized both at the device and at the network side. IoT devices for specific purposes, unlike normal mobile terminals, open up new areas for optimization. A use-case aware network improves the resource utilization, optimizes the power consumption, and adopts robust communication for emergency scenarios. We present algorithms and protocols, which shows huge gains over traditional systems by over 80% in resource allocation (through group based SPS) and over 90% in power consumption (through removal of DRX and measurements).

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