Thesis - draft

NB-IoT

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Contents

1. Intro

The idea of having all devices connected has led to the concept of Internet of Things (IoT). Here all devices such as electric or water meters, household devices and about every thing with built in sensors, are communicating with each other or with a central server via short distance communication or wide area networks (WAN).

One implementation is utilising the LTE standard and modifying it to meet the requirement needed for IoT. Besides the massive volumes it has to handle, there are requirements on coverage, communication complexity and battery life [2].

The devices need to be accessible from hard radio conditions like from house cellar or a technique room in the core. The communications have to be simple for the sake of resilience and low power consumption. Lastly it is expected that the battery to last the live of the device. It is therefore extremely important that no unnecessary transmission is undertaken.

When determining the capacity of the base station, or the serving cell, it is not enough to have the theoretical capacity analysed. The random nature of when the device transmits, increases the chance of collision when the number of devices increases. As mentioned the requirement is to avoid such collision. The capacity therefore reduces when taken this into account.

A suitable approach is to identify the theoretical capacity of an NB-IoT cell. Then introducing randomness into the access, taking into account the possibility of collision. The result is a multi-dimensional space of capacity weighted against probability of collision and number of devices. To further enrich the analysis, the radio condition can be taken into account, introducing further randomness since poorer radio condition results in higher re-transmission probability when the number of devices increases.

The challenge is on the physical channels, when the load increases. The random access can result in collision, making it necessary to resend the package. Re-transmission causes unnecessary communication and extra battery. This is therefore something to avoid.

Keep in mind that NB-IoT is UL-driven service, unlike traditional mobile services that are DL-driven

2. NB-IoT

3GPP defines wide area network (WAN) narrowband internet-of-things (NB-IoT) to handle communication with connected devices. The physical channel structure is the same as LTE, but scaled down to occupy less bandwidth. The downscaling provides flexibility to place the carrier where there is available space. One solution is to place it on a single GSM transmission channel (TCH), and that way integrate it with the GSM network. The other two are co-existing with LTE, where one uses the guard band between LTE channels and the other is embedded into the LTE carrier [1].

The high throughput characteristics of LTE, and the fact that NB-IoT devices do not need to send big volumes of data, gives an opportunity to increase the protection of the transmitted data. This is done by extra padding, more robust coding scheme and modulation. The benefit is increased link budget, allowing up to 20 dB extra attenuation, and decreased probability of wrongly received data, requiring retransmission [2].

NB-IoT devices differ from other mobile devices, in that they aren't downlink critical. The sensor deployment requires data to be transmitted from the sensors, towards other devices or a central service. The uplink is therefore the important direction. It can be further assumed that the devices initiates the communication, not the base station.

An additional design criteria for NB-IoT, is long battery life [2]. Having the extra link budget, it can transmitt with lower power but it is also important to avoid unnecessary retransmission. In the case of retransmission, there is waiting - awake - time and extra transmission. Both require extra battery usage which has to be avoided.

2.1 Channel structure

NB-IoT downlink is defined to use 12 sub-carriers, with each sub-carrier having bandwidth of 15 kHz. That adds up to 180 kHz, which fits perfectly into the GSM transmission channel (TCH) of 200 kHz. The uplink uses either a single sub-carrier, which can be of varying bandwidth: 3,75 kHz or 15 kHz, or it uses 3, 6, or 12 sub-carriers of 15 kHz bandwidth each[3]. The last is the same as for the downlink and the total bandwidth becomes 180 kHz.

It is important to describe the physical channels, since the analysis goes on about identifying when they reach congestion. **Needs to be investigated if the higher layer channels introduce any limitation.**

2.2 Access

As mentioned, NB-IoT is uplink critical communication meaning that the device initiates the communication and the data exchanged is something the device has been collecting. This means that one of the most critical capacity aspects of NB-IoT is how many devices can be accessing the network and how long does it take for the device to „get rid of the data".

The access process is as follows: **These steps have to be verified from [3]**

1. Random access: the device initiates a connection with the base station using the random channel

(a) Here the possibility of collision with other devices occurs i.e. when two devices try to access at same time they interfere and neither of them gets through

(b) **What is the retry mechanism ?**

2. The base station assigns resources on the dedicated channels **freeing resources from the random access channel ??**

3. When the device has gotten its dedicated resources it can begin transmitting

The capacity limit is reached when the number of devices increases, partly due to the probability of collisions and partly due to the capacity of the dedicated channels. **The point of the paper is to identify which one is congested before.**

Notes:

- **Investigate how the paging mechanism is implemented in NB-IoT. There must be some way for the base station to reach the UE.**

2.3 Evaluation points

The limitations when it comes to serving multiple users lies within the random access procedure. The user has limited power and has therefore to make its transmission based on most efficient transmission methods. Collision is important to avoid. Modulation and coding scheme have to navigate between giving the maximum throughput but with best recovery of distorted bits **this should be looked into - find articles evaluating this trade-off**.

When the user has gotten the random access procedure completed and is scheduled on the transmission channels. The next step is the focus of the thesis - how to maximise ??, to be able to service more users and withholding the goal of minimum transmission.w

2.4 Extras

Schlienz (2016) [1] is a very good summary of NB-IoT structure. The references are all 3GPP TS36.2xx, which is the channel structure of LTE - with a chapter covering NB-IoT.

Question: is it sufficient to rewrite Shclienz (2016) and refer to the article, plus the 3GGP standard ?

*** Describe NB-IoT**

There are three implementation methods of NB-IoT. There is standalone, guardband and in-band.

6.4.1 Standalone Deployment: Standalone deployment is a deployment scenario in which operators deploy NB-IoT using existing idle spectrum resources. These resources can be the operator's spectrum fragments with non-standard bandwidths or spared from other radio access technologies (RATs) by refarming.

6.4.2 LTE Guardband Deployment: Guardband deployment is a deployment scenario in which operators deploy NB-IoT in guard bands within existing LTE spectrum resources.

6.4.3 LTE In-band Deployment: In-band deployment is a deployment scenario in which operators deploy NB-IoT using existing LTE in-band resource blocks (RBs). **[GSMA deployment guide]**

In the 3GPP NB-IoT technical specification, chapter 4.2, the radio resources are defined in deep details (if relevant). [1].

In the following work of the focus will be on in-band LTE NB-IoT.

[WHERE IS TTI DESCRIBED !!!]

*** Cover the access method**

Schlienz (2016) is a really god reference to work the access method from.

* Coverage classes - how different classes affect the access mechanism

Here are some outstanding questions. One coverage class something mentioned in the specifikation or is it something suggested in literature.

3. References

References

[1] Schlienz, J., & Raddino, D. (2016). *Narrowband internet of things whitepaper*. White Paper, Rohde&Schwarz, 1-42.

[2] Wang, Y. P. E., Lin, X., Adhikary, A., Grovlen, A., Sui, Y., Blankenship, Y., ... & Razaghi, H. S. (2017). *A primer on 3GPP narrowband Internet of Things*. IEEE communications magazine, 55(3), 117-123.

[3] 3GPP TS 36.201, *3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description*, version 15.2.0, Release 15.

[4] 3GPP TS 36.211, *3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); LTE physical layer; General description*, version 15.14.0, Release 15.

[5] Chen, M., Miao, Y., Hao, Y., & Hwang, K. (2017). *Narrow band internet of things* . IEEE access, 5, 20557-20577.

4. Outstanding

- Is there a code available that makes it possible to emulate the access mechanism and show the clash when the load increases ?

Statement: For a device with 164 dB coupling loss, a 10-year battery life can be reached if the UE transmits 200-byte data a day on average [TR 45.820 v13.1.0, “Cellular system support for ultra low complexity and low throughput internet of things,” Nov. 2015]