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# GROUPING NARROWBAND INTERNET OF THINGS END POINTS WITH CONTROL PACKETS BASED ON MULTICAST PACKET DELIVERY FUNCTIONALITY FROM ENODEB

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## ABSTRACT

Techniques are described herein to create a multicast Narrowband Internet of Things (NB-IOT) User Equipment (UE) group based on a set of four attributes that are not defined in the 3rd Generation Partnership Project (3GPP) Release 14 Standard/Specification. This NB-IOT UE grouping for multicast applications may assist indoor NB-IOT eNodeB (eNB) based deployments.

## DETAILED DESCRIPTION

The 3rd Generation Partnership Project (3GPP) Release 13 and Release 14 Standards/Specifications for Narrowband Internet of Things (NB-IOT) do not define a multicast message option for sending multicast packets to a group of NB-IOT end points or sensors from the NB-IOT eNodeB (eNB). The techniques described herein address this problem.

Multicast has never been considered a primary issue for Long-Term Evolution (LTE) networks, with the exception of narrow and limited use cases relating to optimization of video flows within a given cell. This difference from campus technologies is reasonable in a network structure where distributing data to more than one device would be uncommon. This logic changes with IOT, in which multiple devices of the same type may permanently inhabit a cell, and may need to receive copies of the same data element. However, even within the 3GPP Release 13 and Release 14 Standards/Specifications for NB-IOT, there is no definition of a multicast message option for sending multicast packets to a group of NB-IOT end points or sensors from the NB-IOT eNodeB (eNB). 3GPP is beginning to appreciate the need for multicast support in 5G IOT, but no clear solution has been introduced yet.

At the upper layer, multicast may be viewed as all the subscribers of an Internet Group Management Protocol (IGMP) / Multicast Listener Discovery (MLD) group. However, this Layer 3 representation needs to be translated into a Layer 2 group, and this problem has not yet been solved in the 3GPP context. Techniques are described herein to address this first problem in multicast messaging: the ability to recognize and form device groups within a cell at Layer 2 without requiring the assumption of a Layer 3 multicast group that somehow translates into a Layer 2 group.

Multicast packet delivery in the downlink direction with NB-IOT radio technology eNB has many IoT application use cases which are important for service providers managing IoT networks for IoT Mobile Virtual Network Operators (MVNOs). For instance, there are many scenarios whereby multiple devices in a cell may need to receive the same type of data.

One scenario relates to Firmware Over The Air (FOTA) upgrades provided to a selected group of NB-IOT end points or for a software based manager for a selected group of NB-IOT end points. In this case, each device may be individually connected (unicast) to a management server. Then, at some point in time a large number of devices are individually informed that they should update and all initiate unicast flows for the same upgrade data or firmware image.

Another scenario involves selective delivery of IOT application features (e.g., video traffic, audio traffic, etc.) based on the location of NB-IOT end points from the NB-IOT eNB. For example, members of emergency groups (e.g., first responders to a fire) all need to receive selected team instruction flows from their command centers. The same logic applies to fleet management and any other connected team.

Still another scenario occurs in a high density 5G NB-IOT deployment, where Radio Frequency (RF) congestion is a concern. Here it becomes important to group or classify NB-IOT end points to provide differentiated multicast services for different IOT use cases. Such grouping may limit the impact on airtime due to one-to-many or many-to-many communications. In 5G NB-IOT, these one-to-many flows become common and frequent. For example, a connected board may query the status of parking sensors to refresh the available slots display, whereas previous implementations were relying on individual sensor upstream unicasts, thus ignoring unresponsive sensors.

To implement such multicast services without the expectation of an upper layer grouping system, the NB-IOT eNB should be able to recognize devices that belong to the same group. This recognition may be available with existing L1/L2 tools and software capabilities.

A grouping method that may accomplish these goals is provided herein. The method implements a four-phase system. The first phase identifies NB-IOT User Equipments (UEs) in a cell and differentiates from standard LTE UEs. The second phase classifies multicast NB-IOT UEs using a Downlink Control Information (DCI) index and allocated sub-channels. DCI is a logical block (unit) that carries data for NB Physical Downlink Shared Channel (NPDSCH) or NB Physical Uplink Shared Channel (NPUSCH) data. The third phase organizes multicast distribution using location-based identification of NB-IOT UE groups. The fourth phase optimizes downstream flows using decoding region-based classification of the multicast group. By optimizing LTE air time performance from the NB-IOT eNB in the downlink direction, the need for additional control signals for multicast grouping is limited or suppressed. This NB-IOT UE group specific decoding of regions helps to optimize multicast grouping, which can be applied to deliver additional innovative IOT services. UE group specific decoding regions may improve LTE air time utilization and efficiency.

Figure 1 below illustrates an example system configured to implement the techniques described herein.

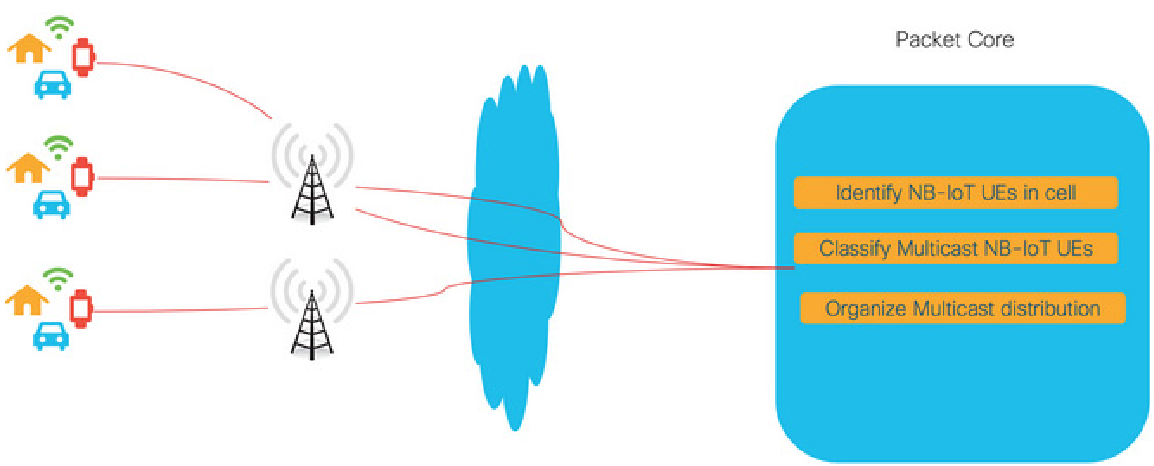


*Figure 1*

In the first phase of the method, NB-IoT UEs are identified in a cell. The Access Point (AP) LTE module reads and records the random access preamble / Packet Random

Access Channel (PRACH) packets. 3GPP standards indicate that NB-IoT devices are expected to be simpler than standard LTE UEs, and will access a network over a simplified channel. In accordance with techniques described herein, this logic may be used not to simplify the channel access, but rather to identify and group IOT UEs by observing their random access preamble / PRACH packets, and observe the distribution of these packets and their repetition. An NB-IOT UE can repeat a random access preamble packet 1, 2, 4, ... , 128 times. This observation method not only allows the system to distinguish NB-IOT devices from regular LTE UEs, but can also be used to group NB IOT devices that present the same access structure.

In one implementation, this grouping technique may be used to display a unique metric (UE density per device type), and may also be used to automatically group devices in a management User Interface (UI). This may allow an administrator to apply policy parameters or network optimization parameters to groups of previously-identified similar devices.

In addition to the random access preamble / PRACH packets, repetitive transmissions are sent from the NB-IOT UE on almost every channel of the NB-IOT UE. By contrast, in traditional LTE (standard UEs), the only repetitive transmission is time interval bundling, with all other transmissions intended for single repetition only. This particular behavior is specific to NB-IOT and may therefore be used to identify NB-IOT UEs (as opposed to regular LTE UEs) and also to group NB-IOT devices by similar transmission characteristics. It will be appreciated that implementing this lower layer method does not necessarily preclude implementations from adding known upper layer methods (e.g., IGMP, MLD, Advanced Video Coding (AVC) pattern recognition, etc.)

After the NB-IOT devices have been identified in the cell in the first phase, the second phase is used to further group NB-IOT devices into meaningful multicast groups. Per the 3GPP Release 14 Technical Specifications (TSs), the Physical Downlink Control Channel (PDCCH) DCI messages are used to inform UEs about their downlink assignments (e.g., location, how often they are repeated, Modulation Coding Scheme (MCS), etc.), and also their uplink grants to the Physical Uplink Shared Channel (PUSCH). PDCCH is also used for broadcast scheduling (e.g., paging, System Information Blocks

(SIBs), etc.) However, the 3GPP Release 14 TSs do not explain or specify multicast packet delivery to a specific set of UEs.

NB PDCCH (NPDCCH) is the physical channel that carries (conveys) DCI. NPDCCH indicates the identifiers of the UEs having data transmitted in the NPDSCH, and also carries some control information such as paging, uplink/downlink assignment, Random Access Channel (RACH) response, etc. An NCCE is the basic unit of the physical block in NPDCCH where DCI data is allocated. NPDCCH splits its area into two subblocks referred to as NCCE 0 and NCCE 1. Formally, the NPDCCH operates as follows. NPDCCH is transmitted by aggregating one or two consecutive NB Control Elements (NCCEs). Here, each NCCE includes of six consecutive subcarriers in a subframe. NCCE 0 occupies subcarriers 0 to 5 and NCCE 1 occupies subcarriers 6 to 11 in a subframe.

Techniques are provided to augment and improve NPDCCH for IOT multicast. If the NCCE is equal to zero in the NPDCCH packet, that NB-IOT UE may be added to a first multicast group. The UE may use subcarriers 0 to 5 for sending the uplink grant information to the NB-IOT eNB. Subcarriers 0 to 5 may also be used for sending the multicast data payload from the NB-IOT eNB to the UEs in this first multicast group.

If the NCEE is equal to one in the NPDCCH Packet, that NB-IOT UE may be added to a second multicast group. The UE may use subcarriers 6 to 11 for sending the uplink grant information to the NB-IOT eNB. Subcarrier 6 to 11 may also be used for sending the multicast data payload from the NB-IOT eNB to the UEs in this second multicast group.

At this stage, the system has identified NB-IOT devices and has organized them into coherent groups. These groups have further been assigned to multicast groups. The third phase involves organizing the multicast data distribution according to these groups.

NB-IOT UEs have cell identifier values / PLMN identifiers or NB Primary Synchronization Signals (NB-PSSs) that carry the physical cell identifier. This element of information identifies where the UE is physically located in an x-y coordinate map. This value, as well as the mean Received Signal Strength Indicator (RSSI) index at which the eNB deployed in the enterprise detects the NB-IOT UE PRACH packet, may be used to approximate the UE RF distance (using RSSI-based trilateration) from the eNB. In most cases, the IOT devices may be static, and therefore the RSSI mean value may not necessarily need to be recomputed often.

Based on this determination, it may be determined whether two or more NB-IoT UEs are at same RF distance from the eNB (or at close RF distance). This knowledge may be used to further create smaller multicast groups. UEs of the same type (first phase) and in the same group (second phase) may be further sub-grouped so as to minimize the overhead of control and data packet delivery from the eNB to the UE group. This further grouping may improve LTE airtime efficiency.

The fourth phase provides a mechanism to ensure that the UE properly detects and receives traffic intended for the group to which the UE belongs. In order to detect whether there is any data (NPDSCH) sent for the NB-IOT UE or to detect any uplink grant for NPUSCH, the UE may monitor (attempt to decode) various regions within downlink subframes sent by the eNB. As per the 3GPP Release 14 TSs, the network does not provide notifications as to the particular regions that the UE needs to continuously monitor. As such, the UE needs to monitor all possible regions that are allowed for NPDCCH and must decode the information in trial-and-error based approach. This process is referred to as "blind decoding." However, the UE does not try to decode every possible combination of resource elements within a subframe. There are a certain set of predefined regions in which a PDCCH may be allocated, referred to as the "NPDCCH search space". The UE monitors only those predefined regions. A group identifier specific approach may be provided whereby a pre-defined region is created for NB-IOT for which the NB-IOT UE may continuously monitor based on the multicast group classification.

Segregation of the NPDCCH search space for the UEs is not performed in an optimized manner in the 3GPP Release 14 TSs. As per the 3GPP Release 14 TSs, the NPDCCH common searching space is based on messages such as Random Access Response (RAR), MSG3, MSG4, etc.

In order for the UE to locate the control information with a reasonable amount of packet decoding complexity, the NPDCCH is grouped into the following search spaces: (1) Type-1 common search space, used for paging; (2) Type-2 common search space, used for random access; and (3) UE specific search space.

If there is a 5G grade dense NB-IOT sensor deployment or a large number of NB-IOT UEs and LTE UEs deployed in an in-band NB-IOT deployment scenario, there may be no difference in the UE specific search space approach as per the 3GPP Release 14 TSs.

This is addressed herein with an NB-IOT multicast group based search space within the UE specific search space. The NB-IOT multicast group derived in the first step may be used for this purpose.

One advantage of partitioning the search space is that any mission critical NB-IOT UEs in a high density deployment need not necessarily decode control packets from the NB-IOT eNB every time. Rather, it may rely on the multicast group based UE search space for decoding. This reduces the control signal decoding time latency for a mission critical NB-IOT UE in an enterprise.

One advantage of these techniques to group NB-IOT UEs is that NB-IOT UE specific or NB-IOT UE group specific search spaces for continuous monitoring may be provided by the NB-IOT eNB or the base station network infrastructure. This classification may assist in NB-IOT UE group specific multicast packet delivery. NPDCCH UE specific search region spaces are further provided. Another advantage of continuously monitoring a dedicated region for the NB-IOT UE may be improved battery efficiency for NB-IOT UEs. Here only the RF distance, and not the physical location, is known. Triangulation may be used to determine whether two UEs are next to each other or on another side of the cell. Because of the additional UE based grouping, control packet decoding complexity for different Radio Network Temporary Identifier (RNTI) values for different UEs may be considerably reduced. Time latency for control packet decode may also be reduced.

As per 3GPP Multimedia Broadcast Multicast Services (MBMS), when a UE/device chooses to leave a service it discards the group identifier and can then stop monitoring the Multicast Control Channel (MCCH) for control information. In MBMS, the subscription, joining, and leaving operations are performed on a per-user basis while the rest of the procedures are performed on a per-MBMS service.

By contrast, as described herein, the NCCE field values in the NPDCCH control packet may be used to decide whether to add a UE to a group or delete it. If so, it may be added to a group, and the UE group to which the UE is added may be identified based on the subcarrier bits used. This helps segregate the UE groups into coherent multicast UE groups for effective multicast packet delivery. This improves on general 3GPP multicast and 5G multicast methods. Furthermore, the UE group may be sub-classified using the PRACH packets based on the distance between the NB-IOT UE and the eNB. This knowledge may be used to create smaller multicast groups. UEs of the same type (the first phase) and in the same group (the second phase) may be further grouped so as to minimize the overhead of control and data packet delivery from the eNB to the UE group. This further grouping results in an improved LTE airtime efficiency when NB-IOT UEs are deployed in in-band mode.

There are no new concerns regarding group-based shared-key cryptography raised by these techniques. If there is a shared key, the trust is established at the time the key is built and exchanged with all the members in the multicast UE group, as per the existing art. This trust appears as the UE is identified as it joins the cell or the multicast traffic flow. In the case of downstream multicast, the fact that a UE has a key indicates that it was previously trusted, and therefore it can decrypt the multicast flow. As such, no new cryptographic challenges are added.

Segregation of the NPDCCH search space for UEs is not performed in an optimized manner in the 3GPP Release 14 TSs. According to 3GPP Release 14 TSs, the NPDCCH common searching space is based on RAR messages / MSG3 / MSG4. If there is a 5G grade dense NB-IOT Sensor deployment or a large number of NB-IOT UEs and LTE UEs deployed in an in-band NB-IOT scenario, there is no difference in the 3GPP approach for a UE specific search space. This issue is resolved using UE specific grouping based search space techniques. This reduces overhead on the UE and UE multicast group for control packet decoding time for mission critical NB-IOT UE groups in high density IOT deployments.

The techniques described herein may avoid scenarios in which one or more members of the multicast UE group fail to receive the data by grouping UEs of similar RF characteristics. In the existing art, if a single UE does not receive the data and the data is not acknowledged, then the packet is lost. If control mechanisms detect the loss, then a directed unicast may be sent in the downlink direction to that specific UE. Because the present techniques provide sub-classifications of the UE group, the risk of loss is lower than current one-rate-fits-all methods. Additionally, members that have already received the data may be also removed from the search space logic for their specific multicast group, and they would therefore not suffer from retransmission.

In summary, techniques are described herein to create a multicast NB-IOT UE group based on a set of four attributes that are not defined in the 3GPP Release 14 Standard/Specification. This NB-IOT UE grouping for multicast applications may assist indoor NB-IOT eNB based deployments. The techniques described herein may reduce and optimize LTE air time utilization and nullify the control packet decoding overhead on the NB-IOT UEs of the multicast group. This may provide reliable multicast packet delivery to the uniquely identified NB-IOT UE group in a high-density 5G grade IOT deployment when NB-IOT is deployed in an in-band deployment mode from the eNB operation mode.