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Rel-17 work scope on IoT and MTC

Huawei, HiSilicon

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Rel-17 work scope on IoT and MTC

	Motivation	Design Targets
NB IoT	**Address further market demands from the real LPWA deployment**	**LPWA Enhancement** • Total replacement of 2G M2M • New use cases with higher date rate and lower latency • Mixed-service with divergence requirement • Multi-carrier operations with new non-anchor carrier design • General system efficiency enhancement: including left work in Rel-16 • IoT relay for further coverage extension and power saving • Inter-RAT mobility between NB-IoT/LTE-MTC and NR
NR MTC	**Enable new IoT and MTC markets beyond LPWA**	**New Market #1: Video Surveillance** • Large number of cameras uploading with several Mbps everywhere in a cell • New UE capability: medium to high end MTC device without changing the minimum bandwidth (5MHz or 10MHz) to reduce cost and power consumption
		New Market #2: Industrial Wireless Sensor Networks (IWSN) • Varied sensors collecting data in factories and logistics • Larger number of connections in local areas with more frequent packet arrivals • Low overhead and power/resource efficient transmission in RRC_INACTIVE state

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Address further market demands from the real LPWA deployment

EVOLUTION OF NB-IOT

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Justification

As the enabler of various LPWA use cases for massive IoT (e.g. sensors, metering, parking, smoke detector, shared bicycle, street light, vehicle tracking, white goods, door lock etc.), cellular IoT technologies NB-IoT and LTE-M have been successfully commercialized over the world.

The evolution in Rel-17 should address further market demands of growing diverse IoT services observed from the real deployment and continue to help operators manage their network running different services in a more efficient way in terms of spectrum usage, system overhead, network energy consumption etc.

- **Total replacement of 2G M2M:** nowadays, NB-IoT module cost is already down to comparable with GPRS. The evolution needs to ensure NB-IoT eco-system is able to carry all existing 2G M2M services as well as provide outstanding LPWA experience.
  - Under same coverage (normal coverage MCL), the average ping latency of GPRS is ~0.7s (minimum DRX cycle 0.47s) and the average ping latency of NB-IoT is ~1.4s (minimum DRX cycle 1.28s).
- **New use cases:** demands from the NB-IoT market to support more IoT applications related to human experience (e.g. wearables including health/fitness/emergency IP based voice etc.) which require higher peak data rate.
- **Mixed-service handling:** improve NB-IoT multiple carrier operation e.g. to support network running different service more efficiently.
- **IoT relay:** further coverage extension and power saving.
- **IoT evolution with 5G NR:** cellular IoT has been commercialized around the world and is capable to connect to 5G CN (ongoing in Rel-16), further harmonizing the evolution of existing CIoT technology within NR is key to fully utilize both eco-systems to support from low-end to high-end IoT use cases.
- **General system efficiency enhancement:** including left work in Rel-16.

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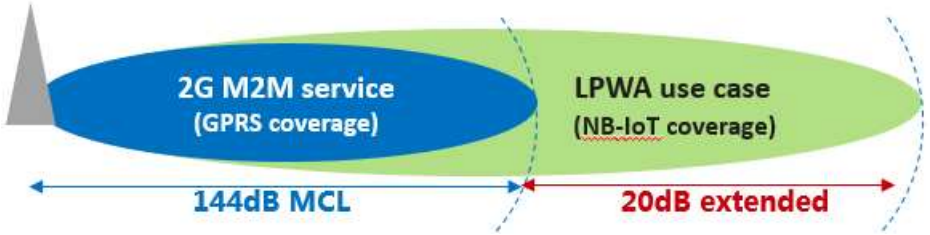
MT latency reduction

Motivation

- One of the original design targets for NB-IoT is to re-farm GSM carriers. NB-IoT module cost (Cat-NB1, NB2) is already comparable with GPRS. Evolution needs to not only provide outstanding LPWA service experience but also ensure CIoT eco-system is able to carry all existing 2G M2M services. The existing 2G M2M services should not see their experience decline when the service migrates to NB-IoT.
- The latency of MT services is mainly restricted by DRX cycle in 2G coverage (normal coverage). However, NB-IoT has minimum 1.28s DRX cycle while GPRS can typically configure to 0.47s in real deployment. Thus, for replacing GPRS, the minimum DRX cycle of NB-IoT should support values similar or less than GPRS.



Main features

- Introducing small paging DRX cycle value for NB-IoT
  - Cell specific and/or UE specific DRX mechanism

Peak data rate further enhancement

Motivation

- There are demands from the market to see NB-IoT support more IoT applications related to human experience (e.g. health/fitness, emergency IP based voice, public safety etc.) other than just connecting things. For example, wearables nowadays are mainly using Bluetooth to connect with cell phones which may require a person take both cell phone and wearable when fitness/running. The real-time data rate of such kind of use cases (e.g. marathoner/swimmer monitoring) could be larger than 200kbps. In addition, firmware upgrade in FOTA also requires higher data rate to save time.
- A bit higher data rate is also good for E2E latency reduction in normal coverage, which benefits some IoT use cases related to human experience in terms of latency e.g. POS machine, smart door lock etc.
- The minimum system bandwidth of NB-IoT is 200kHz while LTE-M is 1.4MHz. If an operator has less than 1.4MHz spectrum, they can deploy NB-IoT but cannot provide larger data rate for certain use cases. There was already some requirement appealed (e.g. real requirement from one operator in RP-172282). Thus evolution should address such gap case to provide a comprehensive cellular IoT solutions to fulfil all deployment cases.
- The ultra-low cost base of NB-IoT is still deployable with chipset available for Cat-NB1/NB2 or new business in the LPWA and low-cost IoT space.

Main features

- Support of higher order modulation 16QAM in NB-IoT for both DL and UL transmission. [RAN1, RAN2, RAN4]
- Support of transmission with wider bandwidth of up to [3] NB-IoT carriers. [RAN1, RAN2, RAN4]
- Introducing new UE category Cat-NB3 with extended TBS table.

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Mixed service handling

Motivation

- Different services may have different requirement in terms of coverage, latency tolerance, battery life etc.
- One NB-IoT cell can operate with multiple carriers while supporting growing diverse IoT use cases. However, some RRC IDLE mode procedure related parameters (e.g. paging, RACH etc.) can only be configured in cell specific way. It would result in mixed services running on one carrier with same configuration. In that case, the system efficiency may degrade if those requirements are divergent.

Main features

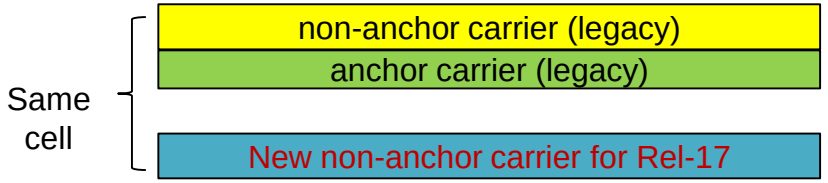
- More efficient support of mixed-service from network perspective by using carrier level differentiation
  - e.g., metering and latency sensitive applications access from different carriers with different parameters configuration.

Improvement of multi-carrier operation

Motivation

- NB-IoT support multi-carrier operation within a single cell. Existing NB-IoT transmission is always allocated on same carrier. The potential frequency diversity between different carriers is not explored.
- A Rel-17 NB-IoT new non-anchor carrier is able to explore the potential to build one network efficiently operate with NB-IoT and others. While the system is backward compatible with legacy UEs. (e.g. reduce overhead, share between NB-IoT/LTE/NR etc.)

Main features

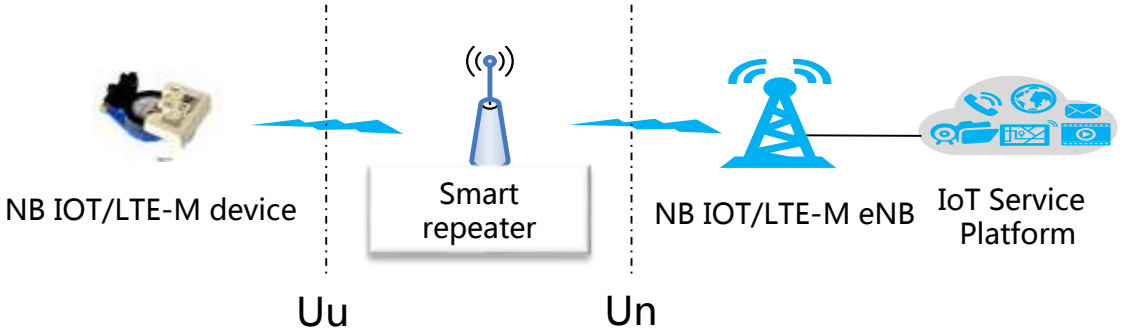


- Support of new Rel-17 non-anchor carrier
  - New EARFCN for FDD with those new offset value introduced for TDD in Rel-15. (anchor and new non-anchor can be deployed in adjacent PRBs in stand-alone mode.)
  - Flexible NRS e.g. the location/pattern of NRS can be configured. (save overhead and network energy)
  - Flexible BW e.g. up to [3] PRBs. (for better coverage or data rate, save repetition etc., at least for DL)
- Support of transmission with frequency hopping/diversity between two carriers
  - For unicast, hopping is supported.
  - For DL broadcast transmissions, additional sync and SI sent on one new non-anchor carrier to explore frequency diversity.
    - RSS can be considered to reduce duplicate transmission in case both NB-IoT and LTE-M are present.
- Carrier level access barring

Further coverage extension and power saving

Motivation

- In some places e.g. basement, the coverage may be poor due to the limitation of setting up a base station (location, power supply, deployment cost, or other aspects). Thus, a low-cost and easy set-up relay is desired to provide further coverage extension.
- On the other hand, it also can save repetitions for poor coverage devices and save battery life for those end devices. In some places e.g. home, all devices are in the coverage of eNB. If a hub-like relay can gather the transmission and forward from/to eNB, the battery life of end devices and the repetitions can be saved.
- It is preferred a Uu based solution (e.g. repeater like) thus the existing devices in the field can get the benefit from such kind of relay deployment. The in-coverage relay can be controlled by the eNB.



Main features

- Uu based relay is preferred (e.g. smart repeater).
- Single additional hop is prioritized.
- The maximum number of end devices supported by the relay nodes is limited up to [X].

Mobility enhancement

Motivation

- Cellular IoT has been commercialized around the world and is capable to connect to 5G CN: harmonizing the evolution of existing CIoT technology within NR is key to fully utilize both eco-systems to support all IoT use cases.
- Inter-RAT mobility between NB-IoT/LTE-MTC and NR should be supported. NB-IoT/LTE-MTC can be regarded as “BWP” of NR.
- Including a study on embedding CIoT within smartphones to provide basic connectivity (e.g., for public safety including message, emergency alarm, etc.) in poor coverage and low power consumption mode. Additionally, using smartphones screen to show visible CIoT signal strength could also be useful.

Main features

- Inter-RAT mobility between NB-IoT/LTE-MTC and NR should be supported.
    - Including study on demand camp in idle mode and fast switch between NB-IoT (LTE-MTC) access and NR SSB access.
- Intra-RAT mobility further enhancement
    - Measurement based cell reselection in additional to RLF for NB-IoT
    - Schemes to reduce neighbour cells SI reading

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General system efficiency enhancement

Motivation

- Some left work in Rel-16, and others.

Main features

- Rel-16 multiple TBs scheduling only applies for 2HARQ in NB-IoT, however in many cases (e.g. poor coverage) only single HARQ can be used.
  - Multi-TB scheduling with single HARQ for both NB-IoT and LTE-M (not supported in Rel-16)
- In some use cases (e.g. smart street light control), a small size common message is delivered to different UEs by unicast for each UE.
  - Support efficient transmission of DL messages to groups of UEs, at least for paging.
- Existing ACK/NACK repetition is configured by RRC signal in NB-IoT, if the repetition is not fit the coverage (e.g. repetition = 4, UE is in good coverage) there might be uplink interference when UE transmits at maximum power.
  - ACK/NACK repetition can be adjusted by DCI in NB-IoT.
- NB-IoT has more than 10 MCS, when UEs in good coverage additional information other than repetition is needed.
  - Finer CQI report for normal coverage in NB-IoT (when repetition = 1)
- Power control enhancement for more efficient resource/interference management
  - DL power allocation for NPDCCH/NPDSCH (not always same as NRS)
  - UL close loop power control for NPUSCH in connected mode.
- More flexible configuration in additional to existing 10ms and 40ms bitmap for invalid subframes.
- For public safety usage
  - Connected mode system information (e.g. ETWS) monitor in NB-IoT.

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Enable new IoT and MTC markets beyond LPWA

DESIGN OF NR-MTC

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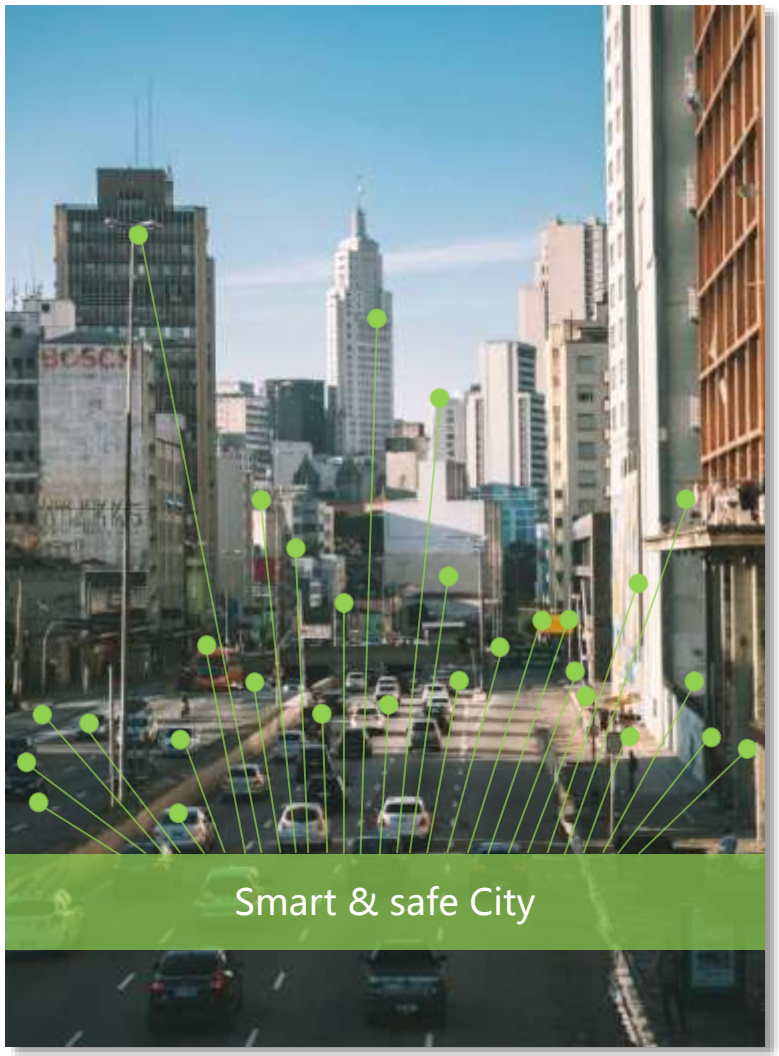
NR-MTC – Enabling New IoT Markets



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New Market #1 – Video Surveillance

- Video surveillance industry with massive connections is an emerging business opportunity for wireless communications.
- In 2016, the number of surveillance cameras in operation reached 200 million, and it is expected to reach 500 million by 2021.

Targets

- Large capacity MTC tailored for specific services, such as video in public services or factory services with low cost and high efficiency
- **Mbps everywhere:** large number of UEs/CPEs with fixed QoS uploading in the uplink everywhere in a cell
  - e.g. enabling 100+ cameras with 2Mbps each per km2
    - 1.5~2 times UL connection density/ SE improvement
    - New UE category, e.g. fixed 5 or 10 MHz
  - e.g. enabling 20+ cameras with 25Mbps each per sector
    - 1.5~2 times UL connection density/SE improvement
    - Efficiently coexisting with eMBB
- **New UE capability:** It is possible to have some new UE capability for medium to high end MTC with reduced capability such a bandwidth and thus having lower cost and lower power consumption

Scenarios	UL data rate
Video surveillance for safe city/village	60~200 cameras per km^2/cell, 2~4Mbps per camera
Fish farm monitoring	24~30 cameras per sector, 25Mbps per camera

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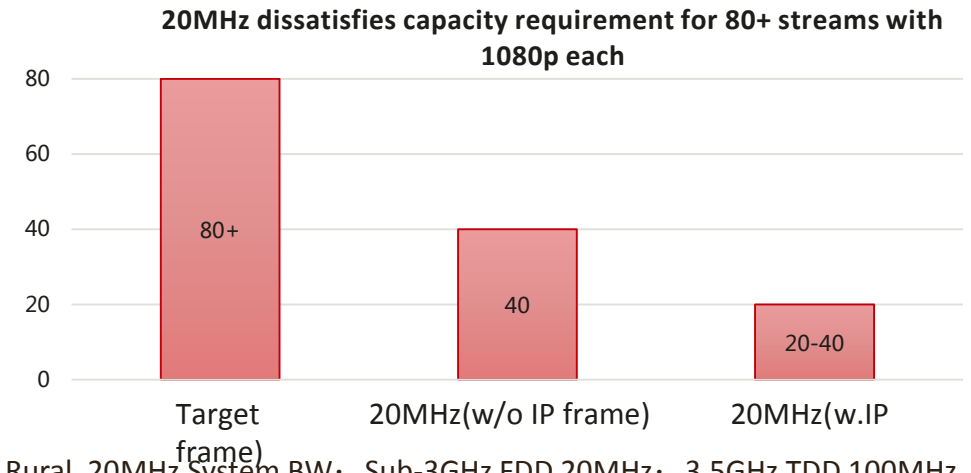
Justification for Video Transmission Enhancement

- **Large capacity demand for video surveillance**
  - One video stream almost equals to **13~17 times that of one eMBB user (40G per month)**
    - 1080P H.265： 670GB per month
    - 720P H.265：502GB per month
  - Real-time surveillance requirement
    - Always ACITVE radio, demanding persistent resource occupancy
    - Heavier burden on capacity than bursty eMBB traffic
  - Safe village applications demands around 100 streams per cell



Rural, 20MHz System BW：Sub-3GHz FDD 20MHz；3.5GHz TDD 100MHz，1/5 UL

- **Cell-edge UEs occupied a great deal of resources. The key point is improving cell edge efficiency**

Minimum bandwidth required for 2 Mbps	
Cell-edge UE (SNR = -3 dB)	**3.42 MHz**
Cell-centre UE (SNR = 10 dB)	**0.58 MHz**

6x

Video surveillance scenario specific

- **Slow-varying channels**
  - Measured results indicated the channel is time-invariant within ~100ms (even if there are obstacles e.g. trees between cameras and base station).
- **Continuous traffic & MU pairing**
  - No “inactive ratio” and fixed users benefit MU pairing.

Video surveillance has large market capacity where improving the spectrum efficiency of the cell edge UEs are the key to increase the number of streams could be efficiently supported.

Enhanced stationary wireless link for video monitoring service

Motivation

- Video surveillance industry with massive connections is an emerging business opportunity for wireless communications, which typically require stable and high data rate in uplink transmission for stationary UEs. However, the current uplink capacity/connection density is either lower than the requirements of video monitoring, or at the cost of consuming large amount of radio resources, and uplink data rate for cell-edge UE may not be satisfied for video. Thus it is meaningful to introduce more enhanced features in NR uplink to serve such high capacity stationary wireless links enabling more related emerging applications.

Main features

Enhanced stationary wireless link for video monitoring service

- Evaluate the UL system capacity in terms of UL connection density/efficiency of NR Rel-15 to support video monitoring service in typical scenarios, including traffic model, simulation assumptions, performance metrics, etc. [RAN1]
- Study and identify UL enhancements for video surveillance UEs [RAN1, RAN2]
  - Enhancement on CSI measurement, scheduling, and HARQ retransmission
  - Overhead reduction of uplink reference signals and control channels for slow-varying channels
  - Mechanisms for the UEs with p oor link quality, e.g., cell edge spectrum efficiency enhancement

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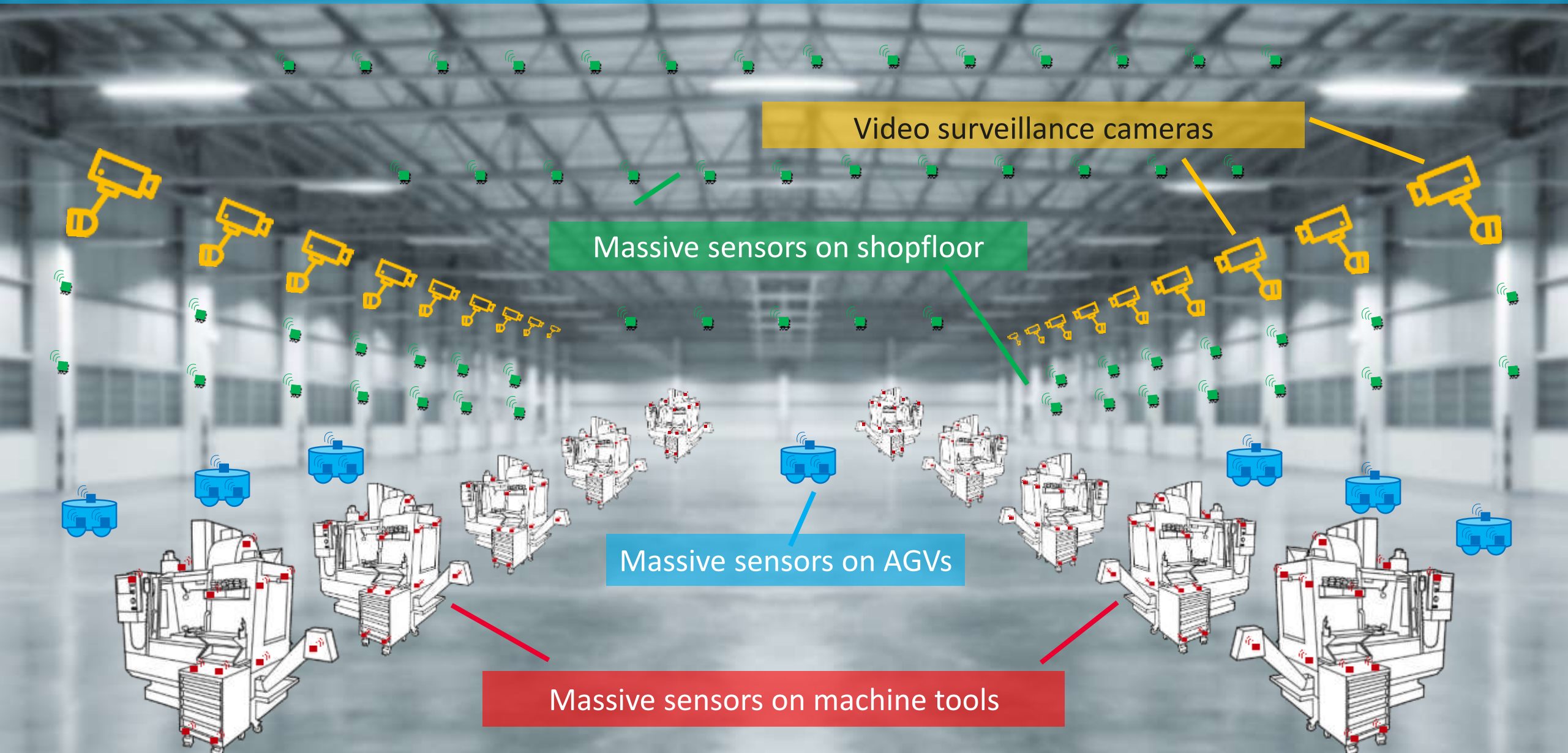
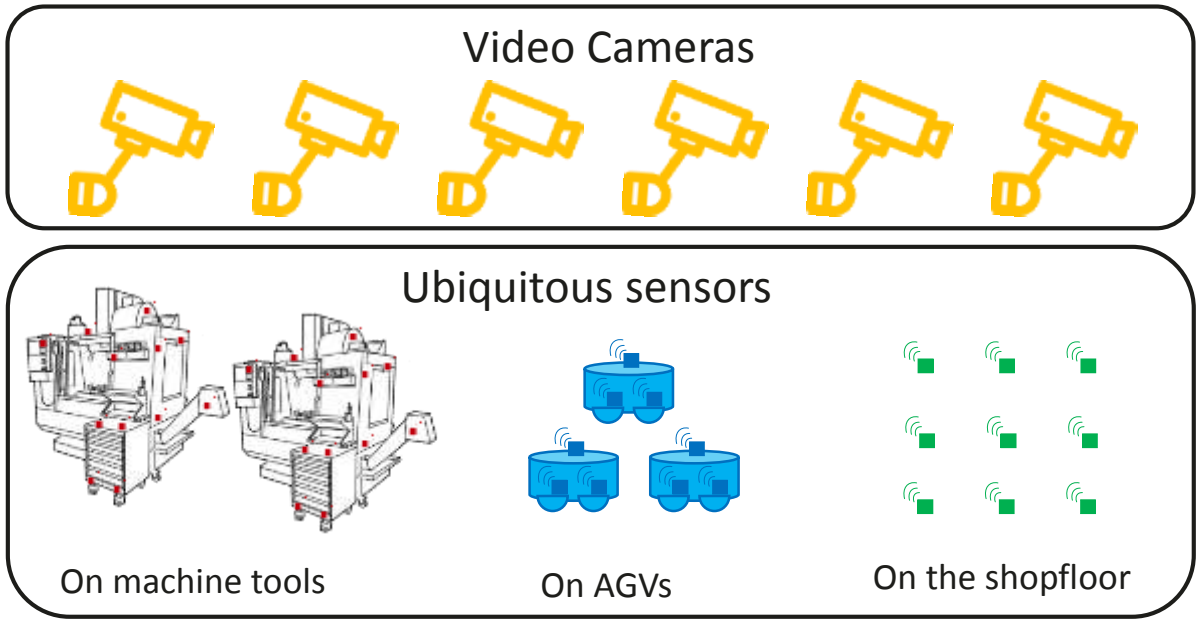
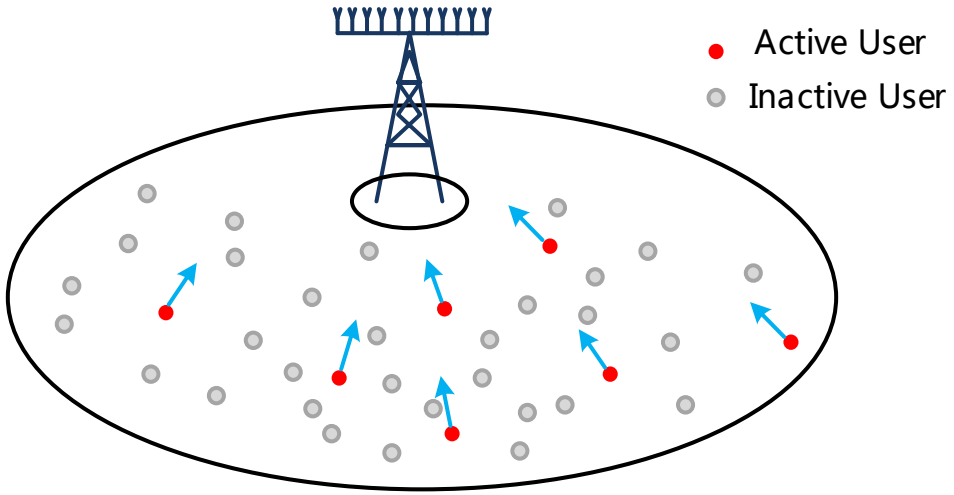
New Market #2 – Industrial Wireless Sensor Networks (IWSN)



New Market #2 – Industrial Wireless Sensor Networks (IWSN)





Targets

- To support more types of varied connections in **Industrial wireless sensor networks (IWSN) for factories and logistics**
  - Dense connectivity in local areas, so coverage may not be the bottleneck issue
- To support larger number of connections in local or macro areas with more frequent activity ratio than the conventional metering
  - About 10 ~ 100x more frequent packet transmission than the conventional 45.820 model (1 packet /2 hours)
  - Some latency requirement, much shorter than metering, but much relaxed compared with uRLLC

Potential Requirement

- INACTIVE state grant-free transmission to support **low overhead, power and low latency transmission**
- More efficient configured grant transmission to better support **large number of connectivity with frequent packets**
- Sidelink relaying to avoid physical blockages such as metal shells
- Enhanced localization to enable new services

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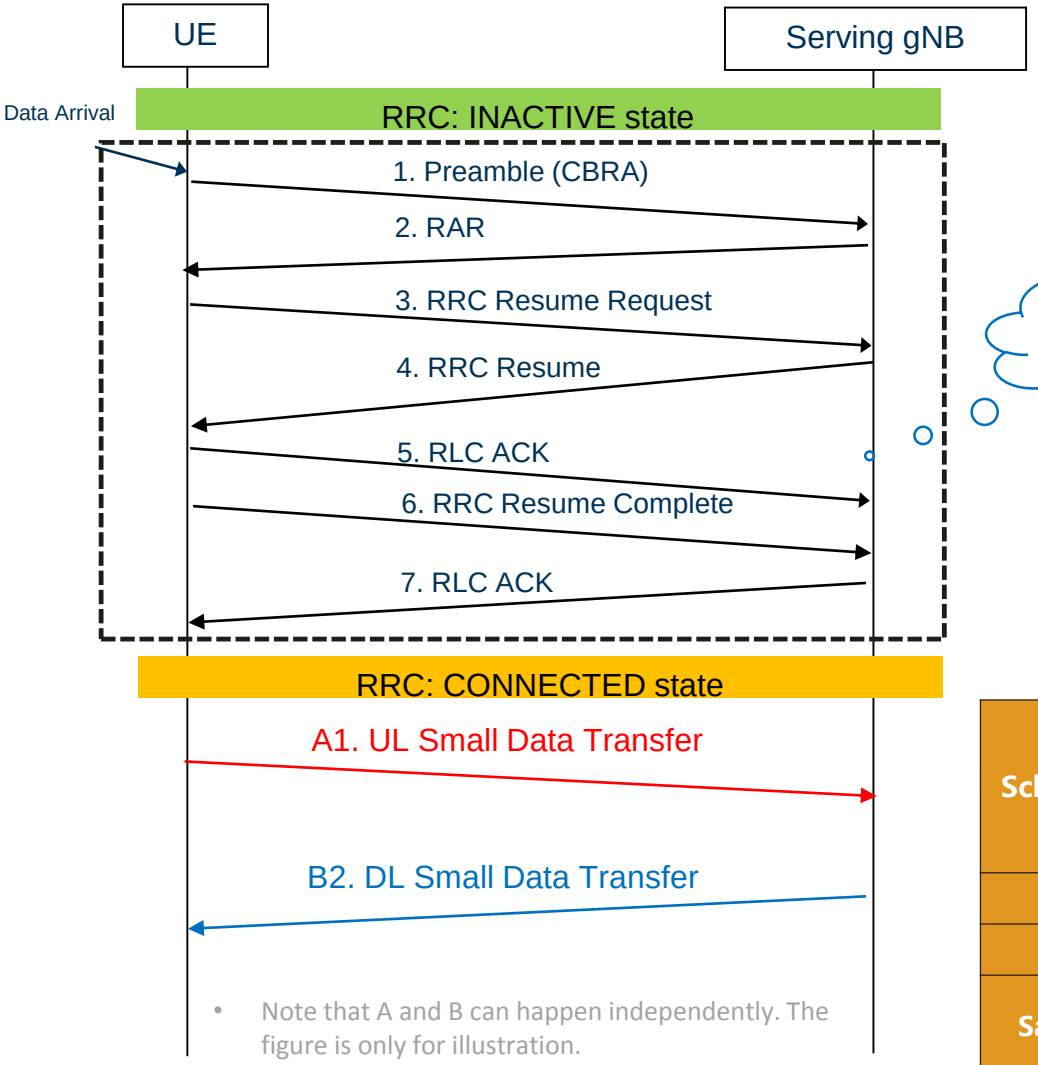
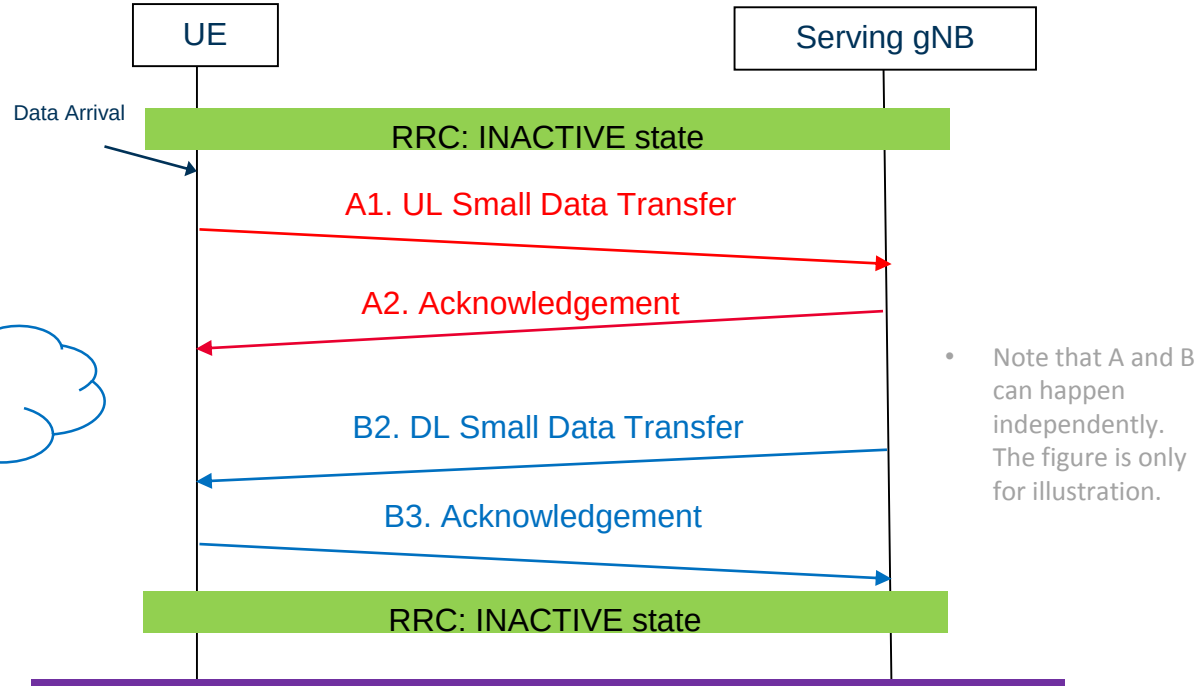
Justification for INACTIVE State Data Transmission (1/2)

Data Tx w. RRC state transition (UL & DL)





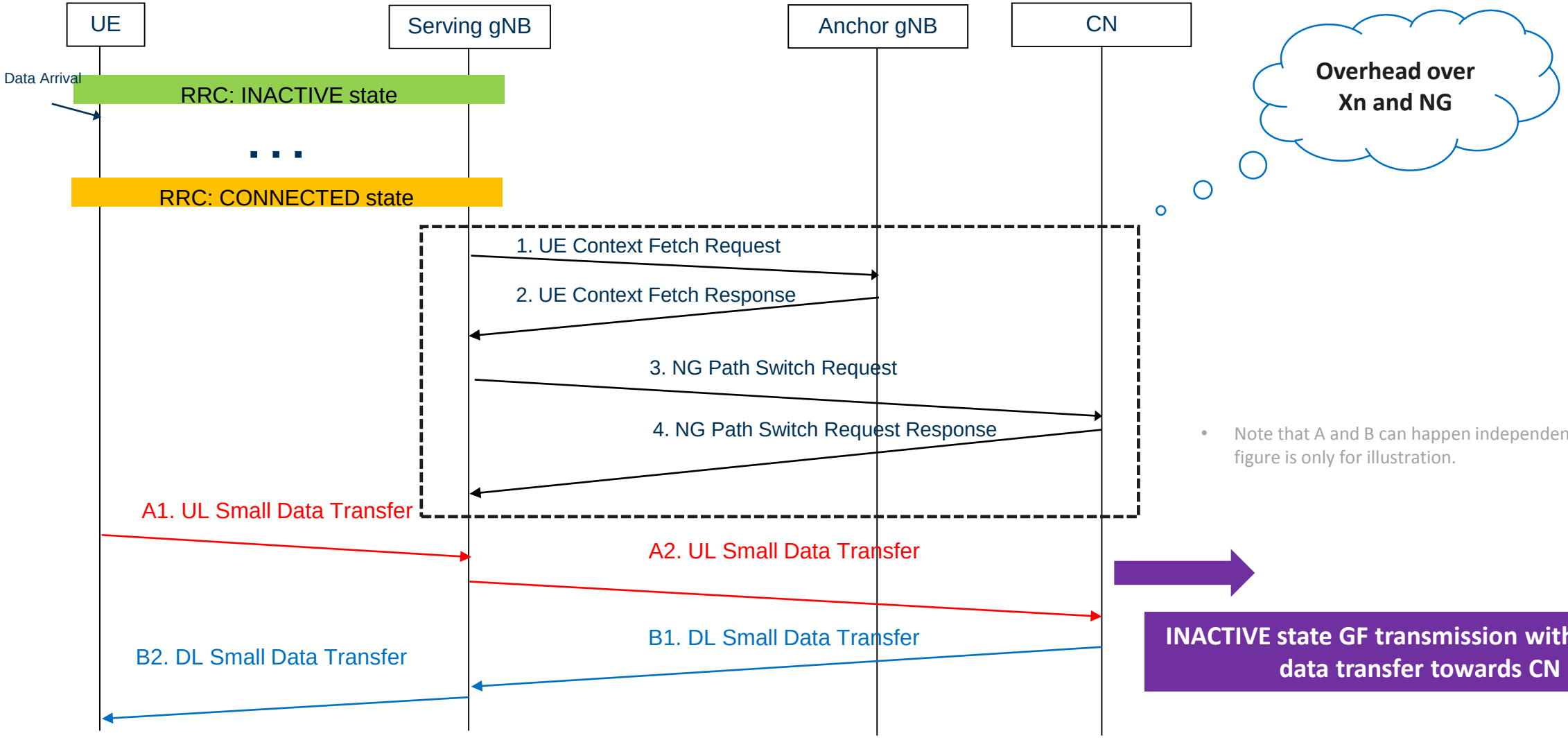
INACTIVE state GF transmission wo RRC state transition

Schemes	UL			DL		
	UP delay (ms)	MAC/RLC/PDCP overhead (bytes)	PHY measure	UP delay (ms)	MAC/RLC/PDCP overhead (bytes)	PHY measure
R16	17.75	62	Yes	20.25	67	Yes
R17	1	22	No	1	27	No
Saving	16.75	40	100%	19.25	40	100%
	94.4%	64.5%		95%	59.7%	

Low overhead and power/resource efficient transmission in RRC_INACTIVE state is needed

Justification for INACTIVE State Data Transmission (2/2)

Data transfer towards CN w. UE context fetch (UL & DL)



- Note that A and B can happen independently. The figure is only for illustration.

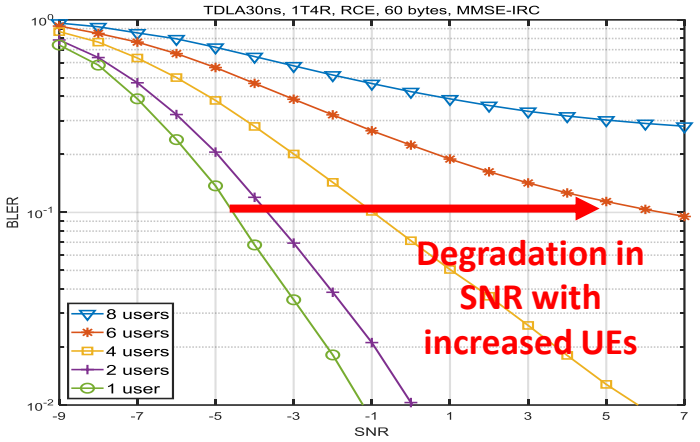
INACTIVE state GF transmission with efficient data transfer towards CN

Low overhead data transfer over Xn and NG in RRC_INACTIVE state is also needed

Justification for More Efficient Grant-free Transmission

Massive connectivity demand for industry wireless sensor networks

- INACIVE state GF data transmission is needed to reduce the signaling overhead and UE power consumption
- Large amount of UEs in the INACTIVE state, demanding large resource reservation for GF transmissions
- More UEs sharing the same T/F resource is needed, resulting in large amount of potential UEs and multiplexed active UE data transmission



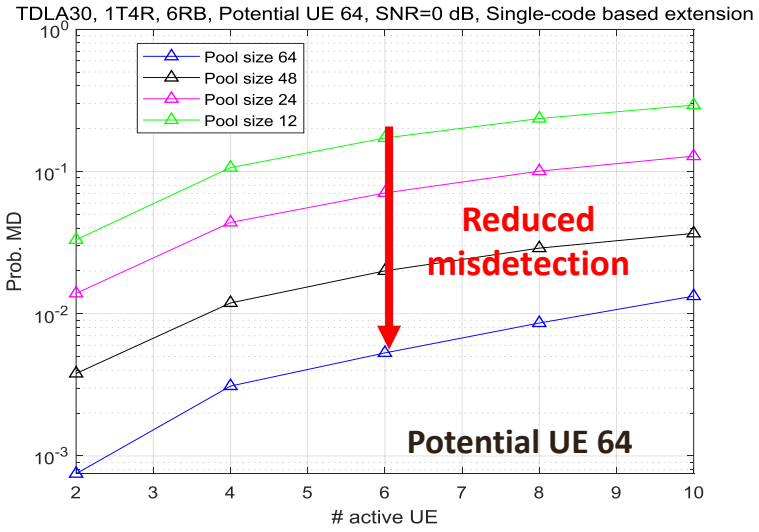
INACTIVE state GF transmission is needed to reduce signal overhead

Resource sharing efficiency to be improved

Examples of collision probability under random active and random selection

Potential UE *N*	Active UE *M*	Resource configuration mode	Pool size *L*		
			12	24	48
12	4	Random active	0	0	0
		Radom selection	0.43	0.23	0.12
24	6	Random active	0.56	0	0
		Random selection	0.78	0.49	0.28
48	8	Random active	0.91	0.5	0
		Random selection	0.95	0.73	0.46

Examples of misdetection w different pool size



DMRS pool size extension is needed to reduce collision probability

Direct small data transmission in RRC_INACTIVE state

Main features

Direct small data transmission in RRC_INACTIVE state

- Study direct UL small data transmission in RRC_INACTIVE state
  - Channel structure and resource allocation to support direct UL small data transmission [RAN1]
    - Reuse channel structure of Rel-16 PUSCH as baseline
    - DMRS enhancement
    - Mechanisms to improve transmission efficiency on shared time/frequency resources
  - Procedures related to direct UL data transmission [RAN1, RAN2, RAN3]
    - Mechanisms for transmission detection and user identification
    - Design of response message to direct UL small data transmission
    - Power control / HARQ, etc.
    - Mechanisms for efficient user plane data transfer towards CN
  - Receiver impact considering realistic user activity detection and data decoding [RAN1, RAN4]
- Study direct DL small data transmission in RRC_INACTIVE state [RAN2, RAN1]
  - Mechanism to support DL user plane data transmission w/o RRC state transition
  - HARQ feedback design
- Link and system level performance evaluation or analysis [RAN1]
  - Traffic model and deployment scenarios
  - Latency, signalling overhead, Power consumption
  - BLER and connection density/efficiency

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Enhanced UL configured grant transmission in RRC_ACTIVE state

Motivation

- UL configured grant transmission is an efficient PUSCH transmission scheme in terms of resource utilization and signaling overhead, and has been adopted by NR since Rel.15 for the support of URLLC and some eMBB services with extremely low-latency requirements.
- UL configured grant transmission can also benefit data transmission in MTC scenario, which can help to improve transmission efficiency and also reduce UE power consumption.
- Compared to URLLC, MTC scenario has much different requirements on e.g. number of users, latency and reliability of the service, etc. To better support NR MTC, enhancements on UL configured grant would be needed.
  - More UEs shared the same T/F resource, less reliability requirement
  - More divergence in the number of repetitions needed due to less stringent latency requirement

Main features

Enhanced UL configured grant transmission in RRC_ACTIVE state

- Study enhancements for UL configured grant transmission in RRC_ACTIVE state [RAN1, RAN2]
  - DMRS enhancement
  - Early termination of UL transmission by explicit ACK feedback
  - Mechanisms to improve transmission efficiency on shared time/frequency resources

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Justification for New UE Capability

- New IoT use cases that can be well met in NR, e.g. economic video for video surveillance for safe city/village and WSN.
  - Up to few Mbps is required.
  - High energy-efficiency required in case of battery-driven sensors is important for WSN.

One example of UL spectral efficiency for NR in Dense Urban/Indoor Hotspot – eMBB (Evaluation configuration A, CF=4 GHz, TDD) (TR37.910 v1.1.0)

Scenarios	Scheme and antenna configuration	SCS (kHz)	Frame structure	ITU Requirement		Channel model A	
						Number of samples	BW=20MHz
Dense Urban	2x32 SU-MIMO, Codebook based, OFDMA; gNB Config = (8,8,2,1,1;2,8)	15	DDDSU	Average [bit/s/Hz/TRxP]	5.4	1	6.57
				5th-tile [bit/s/Hz]	0.15		0.28
Indoor Hotspot (12TRxP)	2x32 SU-MIMO, Codebook based; gNB Config = (4,4,2,1,1;4,4)	15	DDDSU	Average [bit/s/Hz/TRxP]	6.75	1	7.17
				5th-tile [bit/s/Hz]	0.21		0.40

Note: Average UL data rate is about 7/14Mpbs/TRxP for 5/10 MHz.

Observation: IoT device with small bandwidth (e.g. 5/10MHz) can satisfy the data rate requirement and benefit to energy saving.

NR mid-end MTC device types (MTC with small bandwidth) could be defined by selected features of NR and removing requirements for the support of large bandwidths.

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New UE capability for medium to high end MTC devices

Motivation

- MTC with small bandwidth can achieve the data rate (e.g. up to few Mbps) and energy saving requirement for some new IoT use cases such as video surveillance and IWSN
- Not all the mandatory features of Rel-15 may be useful for such device and may result in a cost disadvantage on the market.
- Tailored design for mid-end MTC can be considered to meet the data rate, power consumption, latency, reliability and cost requirements of mid-end MTC devices.

Main features

New UE capability for medium to high end MTC devices

- Identify services, traffic model, and requirements for medium to high end MTC devices (e.g. economic video surveillance for safe city/village, IWSN) [RAN2, RAN1]
- Study and identify suitable bandwidth(s) and potential enhancements to meet the performance requirements, e.g., data rate, power consumption, latency, reliability and cost requirements of medium to high end MTC devices, without reduction of minimum bandwidth [RAN1, RAN2]
  - Enhancements of initial access mechanism and mobility management
  - Scheduling & HARQ, UL/DL control, power control
  - Simplification of CSI measurement/feedback
- Specify the new capabilities for medium to high end MTC devices [RAN4, RAN2]
  - Suitable bandwidth, frequency bands and power class

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Summary

- **NB-IoT** will continue evolution to address further market demands from the real **LPWA** deployment, targeting to replace 2G M2M and support more use LPWA cases with higher date rate and lower latency
  - MT latency reduction
  - Peak data rate further enhancement
  - Improvement of multi-carrier operation
  - Further coverage extension and power saving
  - Mobility enhancement
  - General system efficiency enhancement
- **NR-MTC** will be studied in parallel with NB-IoT evolution to enable new **non-LPWA** markets and new requirements such as video surveillance and Industrial Wireless Sensor Networks (IWSN)
  - New UE capability for medium to high end MTC devices
  - Enhanced stationary wireless link for video monitoring service
  - Direct small data transmission in RRC_INACTIVE state
  - Enhanced UL configured grant transmission in RRC_ACTIVE state

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