Demo Abstract: CDMA-based IoT Services with Shared Band Operation of LTE in 5G

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Abstract—With the vision of deployment of massive Internet-of-Things (IoTs) in 5G network, existing 4G network and protocols are inefficient to handle sporadic IoT traffic with requirements of low-latency, low control overhead and low power. To suffice these requirements, we propose a design of a PHY/MAC layer using Software Defined Radios (SDRs) that is backward compatible with existing OFDM based LTE protocols and supports CDMA based transmissions for low power IoT devices as well. This demo shows our implemented system based on that design and the viability of the proposal under different network scenarios.

Index Terms—5G, Internet of Things (IoT), CDMA, LTE, heterogeneous network, experimentation, open air interface, USRP

I. INTRODUCTION

With exponential growth of IoT devices\textsuperscript{1}, the 5G network will experience a variety of traffic patterns not prevalent in earlier 4G systems. IoT devices often transmits short sporadic messages, which are not well suited to the high data traffic and connection-oriented modes associated with legacy 3GPP networks resulting in high service latency and excessive control overhead. In order to access the network, a User Equipment (UE) has to follow attachment, authentication and bearer establishment procedure which account up to 30\% of control plane signaling overhead. Furthermore, a UE goes into the Idle state if it has been inactive for more than 10 seconds (applicable for many targeted IoT applications) and the UE needs re-establish the bearer for the next transmission. Latency for the Idle to connected state is \(\sim 60\) ms\textsuperscript{2}. With the dense deployment of IoT devices, current 4G network will be extensively overwhelmed by the surge in both traffic and control plane signaling load. The 5G network needs the design provision to accommodate heterogeneous IoT applications at very high scale with low latency and low control overhead across both the radio access network and core network.

The goal is to operate in the same band as current LTE, thus not requiring any separate channel allocation, and is backward compatible with the 4G network\textsuperscript{3}. This motivates us to propose CDMA-based low power IoT transmission for the shared band operation of IoT and LTE devices. With the proposed CDMA-based cross-layer MAC and Physical layer solution, we achieve low latency, short-message and long range communication required for low-power IoT devices. The

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{packet_format.png}
\caption{Packet format of CDMA-based IoT data transmission}
\end{figure}
CDMA-based IoT transmission is prototyped using a software-defined radio (SDR) platform using GNU radio and Universal Software Radio Peripheral (USRP) (see Fig. 2). USRP Hardware Drivers (UHD) are used to transmit/receive samples to/from the USRP. The CDMA transmitter and receiver code is developed on top of UHD in C++ and C, respectively, to process and decode CDMA packets in real time. Intel(R) Core i7 4th Generation CPU (3.60 GHz) machines are used in performance mode. Developing CDMA receiver is particularly challenging to detect CDMA packet considering random wireless channel and critical time constraints of real-time signal processing. For example, to detect beginning of the packet, we perform cross-correlation of a known 64-bit preamble and 10,000 received samples (equivalent to size of a packet) at one instance. Each instance takes processing time of 160 µs including 100 µs for reading samples at sampling rate of 1 MSps and 60 µs for running correlation function. We choose sampling rate 1 MSps to avoid overflowing of samples at receiver which causes due to higher sampling rate. This parameter also restrict the maximum achievable data rate for the CDMA transmission. Furthermore, a packet is detected if the peak value of the cross-correlation output is greater than certain threshold which is a function of SINR. Here the choice of the threshold becomes critical. If it very low, then there is significant false packets detection which eventually get discarded while checking the packet CRC. At higher threshold, packets gets missed in the detection function. So far, we have achieved CDMA transmission with low SINRs (0 - 5 dB) with packet error rate up to 5%, mostly due to the missed detection.

IV. DEMO DETAILS

Our demo evaluate the scenarios of (1) multiple IoT UEs connected to an eNB and, (2) coexistence of an IoT CDMA link and an LTE link. IoT nodes are realized using USRP series X310 and/or B210. LTE transmission is enabled using openair-interface (OAI) where OAI is a PC-hosted open sourced SDR platform [6]. The LTE UE is connected to the LTE eNB using FDD mode, 5 MHz bandwidth, transmission mode 1, and MCS value 9 for uplink / downlink (QPSK modulation).

1) Data Transmission from Multiple IoT UEs: The scenario of multiple IoT UEs connected to the single eNB poses the challenge of increased signal processing complexity at the receiver (eNB) where each UE spreads the message with separate Hadamard code and data transmission is asynchronous. Taking an example of two IoT links, we evaluate the overall implementation robustness and characterize packet-error and packet-detection rates of IoT link with respect to the SINR. The performance is evaluated under variable IoT payload (1-15 Bytes) and transmission delay between packets. This case could further be extended for multiple IoT UEs (> 2).

2) Coexistence of IoT link and LTE: Scenario shown in Fig. 3 aims to evaluate performance of the shared band operation of LTE and CDMA-underlay IoT link. In demo, the LTE link is used for video transmission while the CDMA channel is used for short text messages. This scenario provides insight on design details of CDMA-underlay IoT protocol considering OFDMA structure of LTE. We are currently integrating IoT eNB and OAI/LTE eNB into one unified eNB.

V. CONCLUSION

With the massive deployment of IoT devices, the current 4G network will be overwhelmed by the surge in control plane signaling overhead and network latency. This motivated us to design a CDMA-based cross-layer PHY/MAC protocol for IoT devices. The proposed IoT system coexists with in-band LTE operation and allows uplink sporadic IoT data transmission without a need of resource allocation from the LTE network. We implemented the proposed protocol using software-defined radio platform for exemplary scenarios as a proof-of-concept.

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