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Research Article

# Evaluation of Predicted Throughput in TDD- LTE Systems

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**ABSTRACT**

This paper examines the downlink throughput evaluation of Time division duplex Long Term Evolution (TDD-LTE). The system efficiency is assumed to be equal to the Shannon boundary. Pilot tones etc. is taken from TDD-LTE. Furthermore the packet header is part of the calculated throughput as it is highly dependent on the specific network. A large number of connected terminals will give a higher header/payload ratio, and for this reason it is not calculated in this investigation. Calculations show that RLAN's deployed in this frequency band produces high interference cannot supply high capacity access to internet. Only the rural case is investigated, and the interference radius is limited to 150 kilometres (a BDA2GC maximal radius is in this paper assumed to be 90 kilometres). Results show the capacity for a 20 MHz LTE-TDD systems as function of signal to noise ratio (SNR).

**Keywords:** Throughput, TDD, LTE, RLAN, SNR and BDA2GC.

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ELECTRONICS RESEARCH ARTICLE

# Evaluation of Predicted Throughput in TDD- LTE Systems

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**ABSTRACT**

This paper examines the downlink throughput evaluation of Time division duplex Long Term Evolution (TDD-LTE). The system efficiency is assumed to be equal to the Shannon boundary. Pilot tones etc. is taken from TDD-LTE. Furthermore the packet header is part of the calculated throughput as it is highly dependent on the specific network. A large number of connected terminals will give a higher header/payload ratio, and for this reason it is not calculated in this investigation. Calculations show that RLAN's deployed in this frequency band produces high interference cannot supply high capacity access to internet. Only the rural case is investigated, and the interference radius is limited to 150 kilometres (a BDA2GC maximal radius is in this paper assumed to be 90 kilometres). Results show the capacity for a 20 MHz LTE-TDD systems as function of signal to noise ratio (SNR).
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## I. INTRODUCTION

To address this growing mobile broadband demand, the 3GPP standards body released the next technological step, Long Term Evolution (LTE). LTE is designed to substantially improve end-user throughputs, increase sector capacity and reduce user plane latency. It is a simple and flat network architecture that delivers a significantly improved user experience with full mobility, resulting in low operating costs for operators. LTE is the logical next step for over four billion subscribers on 3GPP networks. Already over 100 global operators are committed to deploying LTE and have commenced technical evaluation and trials. FDD LTE, which uses a paired spectrum, one for uplink and the other for downlink, is the traditional modulation used by 3GPP operators and gained an early lead in LTE deployments.

TDD-LTE uses a different approach, a single frequency sharing the channel between transmission and reception, spacing them apart by multiplexing the two signals on a real time basis. While FDD transmissions require a guard band between the transmitter and receiver frequencies, TDD schemes require a guard time or guard interval between transmission and reception. The time must be sufficient to allow the signal travelling from remote transmitters to arrive before a transmission is started and the receiver inhibited.

Typically more data travels in the downlink direction of a cellular telecommunications system, suggesting that the capacity should be greater in the downlink direction. TDD-LTE systems make this possible by changing the number of time slots allocated to each direction. Often this is dynamically configurable, so it can be altered to match the demand. Another characteristic of TDD-LTE transmissions is the aspect of latency. Due to the time multiplexing between transmit and receive, there can be a small delay between the data being generated and it being actually transmitted.

## II. CAPACITY ESTIMATIONS FOR BDA2GC BASED ON LTE

This paper tries to investigate what capacity and throughput a BDA2GC system based on LTE can achieve in a rural RLAN deployment scenario. The calculations are based on the Shannon bound with LTE specific corrections for effective frequency usage, overhead and pilot tones. Possible uplink/downlink configurations for a LTE-TDD system are summarized in Table 1.

Table. 1. LTE-TDD uplink/downlink configurations.

| Uplink/downlink configuration | Downlink-to-Uplink Switch-point periodicity | Subframe number | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 0 | 5 ms | D | S | U | U | U | D | S | U | U | U |
| 1 | 5 ms | D | S | U | U | D | D | S | U | U | D |
| 2 | 5 ms | D | S | U | D | D | D | S | U | D | D |
| 3 | 10 ms | D | S | U | U | U | D | D | D | D | D |
| 4 | 10 ms | D | S | U | U | D | D | D | D | D | D |
| 5 | 10ms | D | S | U | D | D | D | D | D | D | D |
| 6 | 5 ms | D | S | U | U | U | D | S | U | U | D |

Where D means downlink, U means uplink and S is the switch between downlink and uplink and consists of three parts, DwPTS (downlink part), GP(guard period) and UpPTS(uplink part). The different DwPTS, GP and UpPTS configurations are in the normal case:

Table2. Normal LTE-TDD uplink/downlink configurations.

| | DwPTS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 12 | 11 | | 10 | | 9 | | 3 | |
| GP | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 9 | 10 |
| UpPTS | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 |

The downlink part (DwPTS) can be 3, 9, 10, 11 or 12 symbols. Depending on the DwPTS value the guard period (GP) and the uplink can differ. Capacity estimations are based on different uplink/downlink configurations as well as different configurations of the special sub frame S in order to establish both a best case and a worst case configuration scenario.

### *A) The Shannon bound*

The channel capacity is the tightest upper bound on the amount of information that can be reliably transmitted over a communications channel in a given scenario (bandwidth, noise and interference).
For a SISO (single input, single output) system the Shannon bound is (in bits per Hertz). All equations are in logarithmic scale (dB)

$$SISO = log_2\left(1 + 10^{S/10 \times N}\right)\left[\frac{Bit}{Hz \times s}\right]$$

For multi antenna systems the theoretical increase in SNR is maximum = $N_{receive} \times N_{transmit}$ for none correlated paths. In figure 1 the Shannon bound for different antenna configurations are depicted. Perfect orthogonality is assumed.

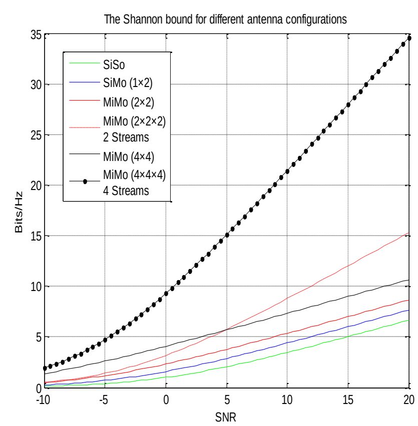



Fig. 1. The Shannon bound from SISO up to 4×4×4 MIMO (4 streams).

### *B) Transport capacity of LTE*

From a radio point of view, LTE is very close to the Shannon bound and in the following calculations LTE is assumed to have a channel capacity that is only limited by the Shannon bound. This slightly overestimates the LTE capacity but is accurate enough for this study.

### *C) Spectral efficiency*

The spectral efficiency of a LTE system can be calculated as

$$E = \frac{BW}{ChBW}$$

Where BW is the bandwidth and Ch BW is the channel bandwidth. BW is calculated by multiplying the number of resource blocks with the subcarrier spacing and the number of subcarriers per resource block.

That is

$$E = \frac{NRB \times SCS \times RB}{ChBW}$$

For a 20 MHz (ChBW) LTE system:

NRB (Number of Resource Blocks) = 100

SCS (Sub Carrier Spacing) = $15 \times 10^3$

RB (Number of subcarriers per Resource Block)

Hence the spectral efficiency of a 20 MHz LTE system is 0.90.

*D) Time domain structure of LTE*

With normal prefix structure a LTE system transmits 14 OFDM symbols per sub frame. With extended prefix structure 12 OFDM symbols are transmitted in one sub frame. Each symbol is nominally (1/spectral efficiency).The efficiency in the time domain can be calculated as

$$D\ efficiency = \frac{Number\ of\ OFDM\ symbols\ per\ frame}{Length\ of\ subframe \times spectral\ efficiency}$$

The length of a sub frame is 1 ms, the number of OFDM symbols are 14 or 12 depending on the structure (normal structure gives 12 OFDM symbols per sub frame). The spectral efficiency can be calculated as explained in the previous section.

For a LTE system with spectral efficiency of 0.9 that is transmitting 14 OFDM symbols each sub frame the TD efficiency is

$$D\ E = \frac{14 \times \frac{1}{15 \times 10^3}}{1 \times 10^{-3}} = \quad 0.93$$

*E) Pilot tones*

During one slot (7 symbols, 0.5 ms) 4 reference symbols are transmitted in each resource block. This leads to a reduction of 4/ (12*7) for a SISO system. For MIMO systems the overhead is increased due to the fact that only one antenna can send a reference signal on each carrier at a specific time. This gives 4×2×2 occupied slots and a reduction of 2×2×4/ (12×7×2) for a 2 MIMO system. A 4 MIMO system has a reduction of (4×2+2×2) ×4/ (12×7×4).

*F) Control signaling overhead*

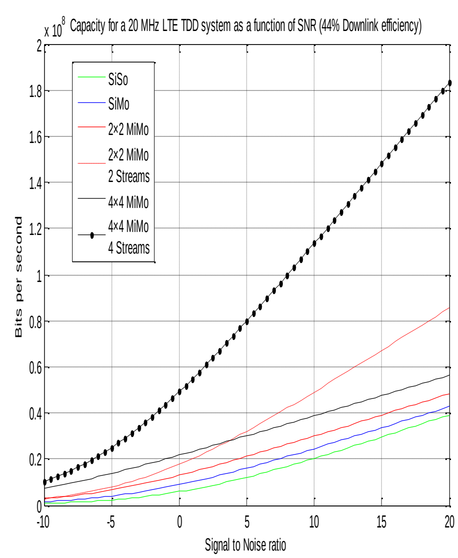
In each sub frame the 1-3 first symbols are used for control signaling, since there is no mixing of control signaling and data in an OFDM symbol. The more users in a cell, the more control signaling are needed, for the BDA2GC system only 1 symbol for control signaling is assumed. This gives an available payload of$\frac{-1}{4}$ .

*G) Uplink/downlink configuration*

If uplink/downlink configuration number 1 (in table 1) is used, 4 out of 10 sub frames are used for downlink. 2 sub frames are switch sub frames and 4 are used for uplink. In the switch sub frames 3-12 symbols can be used for downlink transmission. This gives a downlink efficiency of ((4×14+2×3)/ (10×14) to (4×14+2×12)/ (10×14) = 44% to 7%.

## III. CAPACITY FOR A LTE SYSTEM AS A FUNCTION OF SNR

An LTE system (considered to be on the Shannon boundary) that is subject to the above reductions the result (as a function of Signal to Noise ratio) have a channel capacity that is depicted below, this capacity includes the payload header that needs to be removed before the "user data capacity" is calculated.



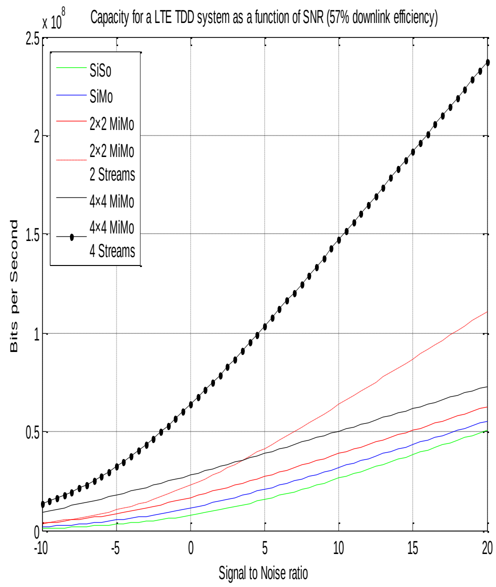



Fig. 3. Channel capacity for a 20 MHz LTE TDD with different uplink/downlink configurations that gives a downlink efficiency of 44 % and 57 %.

## IV. CONCLUSIONS

Long Term Evolution (LTE) is the next generation OFDMA-based technology of choice for most 3GPP. In this paper, we explored downlink throughput evaluation of Time division duplex Long Term Evolution (TDD-LTE). With the envisaged throughput and latency targets and its emphasis on simplicity, spectrum flexibility, uplink/downlink flexibility, added capacity, and lower cost per bit, TDD-LTE is destined to provide many benefits.

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