A NS-3 Module for LTE UE Energy Consumption

Thomas Valerrian Pasca
Akilesh badrinaaraayanan
Arjun V Anand
Bheemarjuna Reddy Tamma

NeWS LAB
Department of Computer Science and Engineering
Indian Institute of Technology - Hyderabad

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Outline

Introduction

1. NS-3 is a quite popular open-source network simulator which has support for Wi-Fi, WiMAX, and LTE.
2. The availability of high number of validated and well-maintained models make NS-3 one of the most preferred open source network simulator for researchers.
3. NS-3 supports limited power control features which are widely used in spectrum model, but it does not have sophistication for measuring energy expenditure in LTE interface of a UE.
4. We developed LTE UE energy module using commercial UE power profile from [JLM+12].

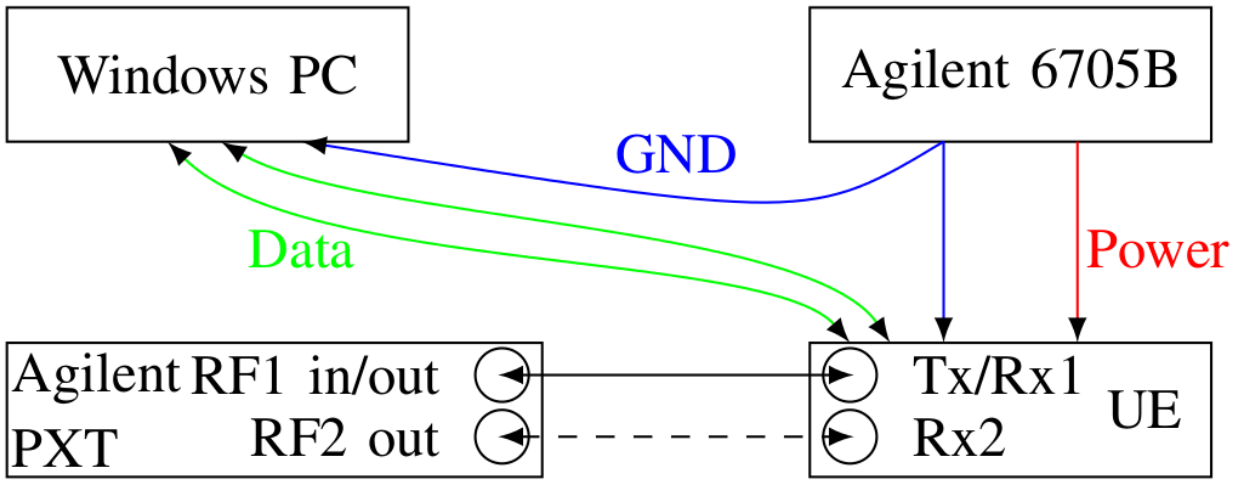
Need for LTE UE Energy Module

1. Energy awareness is required by most of the decision making algorithms.
2. To analyse the power efficiency of network based handover or scheduling algorithm, UE energy module plays a vital role.
3. In NS-3 support for LTE UE energy module is not developed.
4. To develop energy aware handover algorithms.

LTE UE power consumption Model - Setup

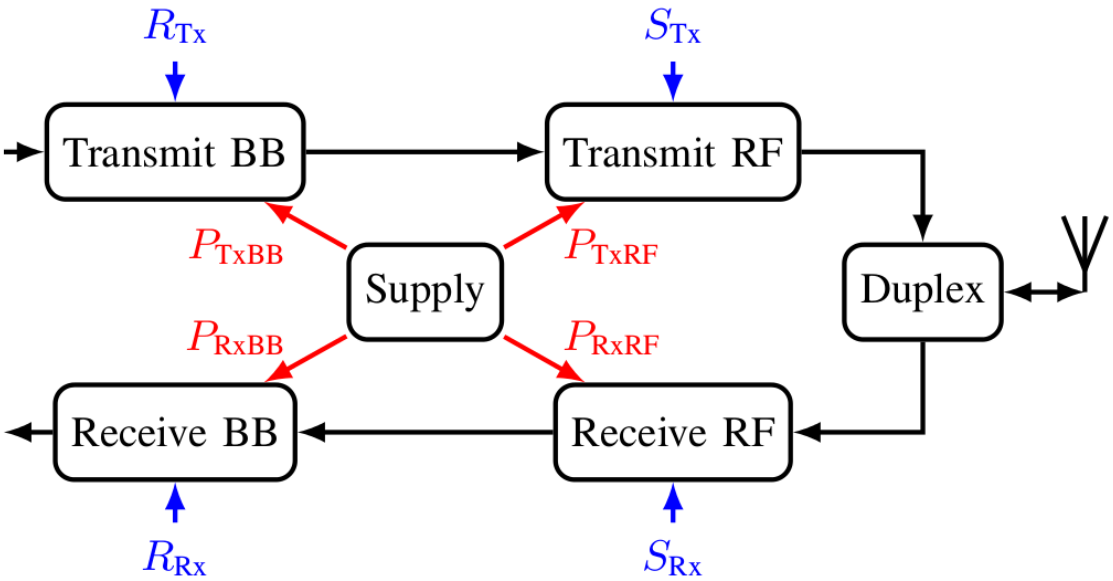
According to experiments conducted by authors in [JLM+12].

- A commercial LTE UE is used for experiments with power supply from Agilent 6705B DC measurement power supply (5 V, 1 A).
- The commercial UE follows its power dissipation profile as specified in [3GP].



LTE UE Power Consumption Model - blocks

The major components of power consumption in UE as given in [JLM+12]



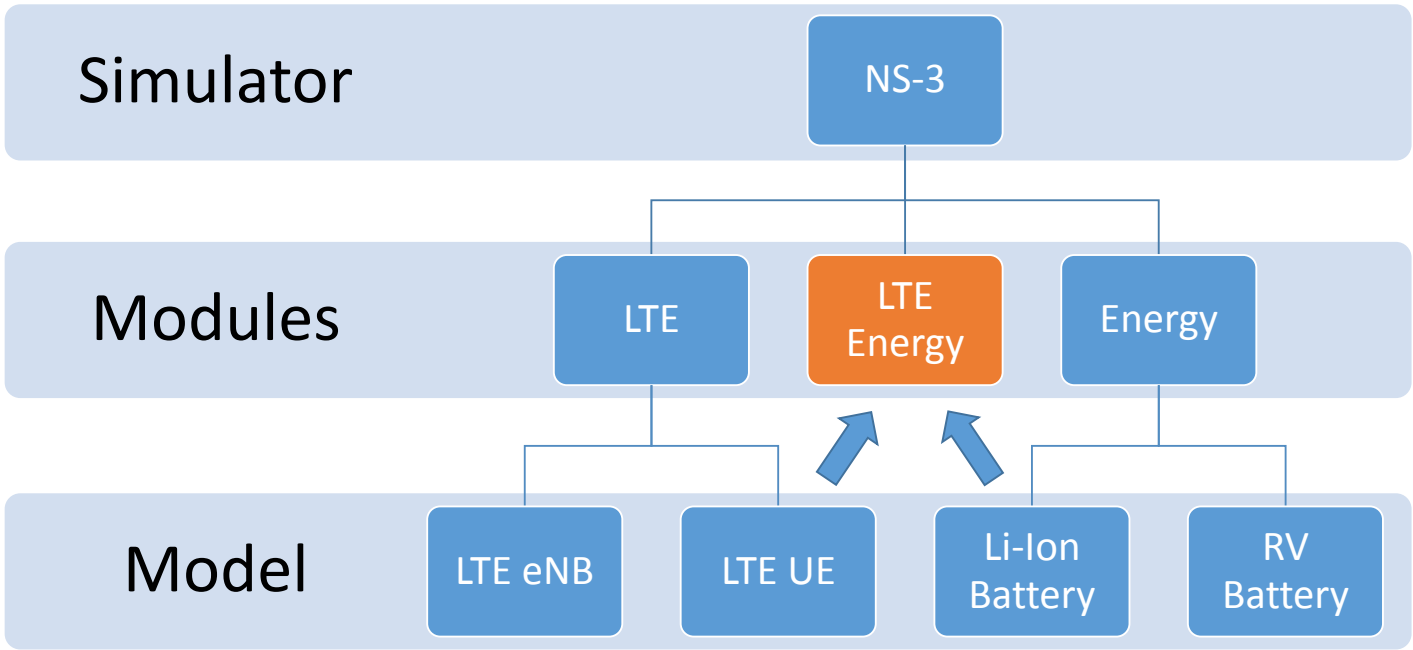
1. Transmitter Base Band Module (TxBB)
2. Transmitter RF Module (TxRF)
3. Receiver Base Band Module (RxBB)
4. Receiver RF Module (RxRF)

LTE UE Power Consumption Model I

$$P_{tot} = m_{idle} \cdot P_{idle} + \overline{m_{idle}} \{P_{con} + m_{Tx} \cdot m_{Rx} \cdot P_{Rx+Tx} + m_{Rx} \cdot [P_{Rx} + P_{RxRF}(S_{Rx}) + P_{RxBB}(R_{Rx}) + m_{2cw} \cdot P_{2cw}] + m_{Tx} \cdot [P_{Tx} + P_{TxRF}(S_{Tx}) + P_{TxBB}(R_{Tx})]\} \quad [Watt] \tag{1}$$

P_{tot} - Total power consumed.
P_{idle} and P_{con} - Power consumed in idle mode and connected mode.
m_{idle} and $\overline{m_{idle}}$ - Time spent by a UE in idle and connected states.
P_{Tx} and P_{Rx} - Power spent in transmit and receive chains.
RxRF and *RxBB* - Power consumed by components of receiver chain.
TxRF and *TxBB* - Power consumed by transmit chain components.
2CW - Increased consumption when using two codewords (CW) in DL.
S - Rx and Tx power levels.
R - Rx and Tx data rates.

LTE Energy Module Hierarchy and Dependencies in NS-3



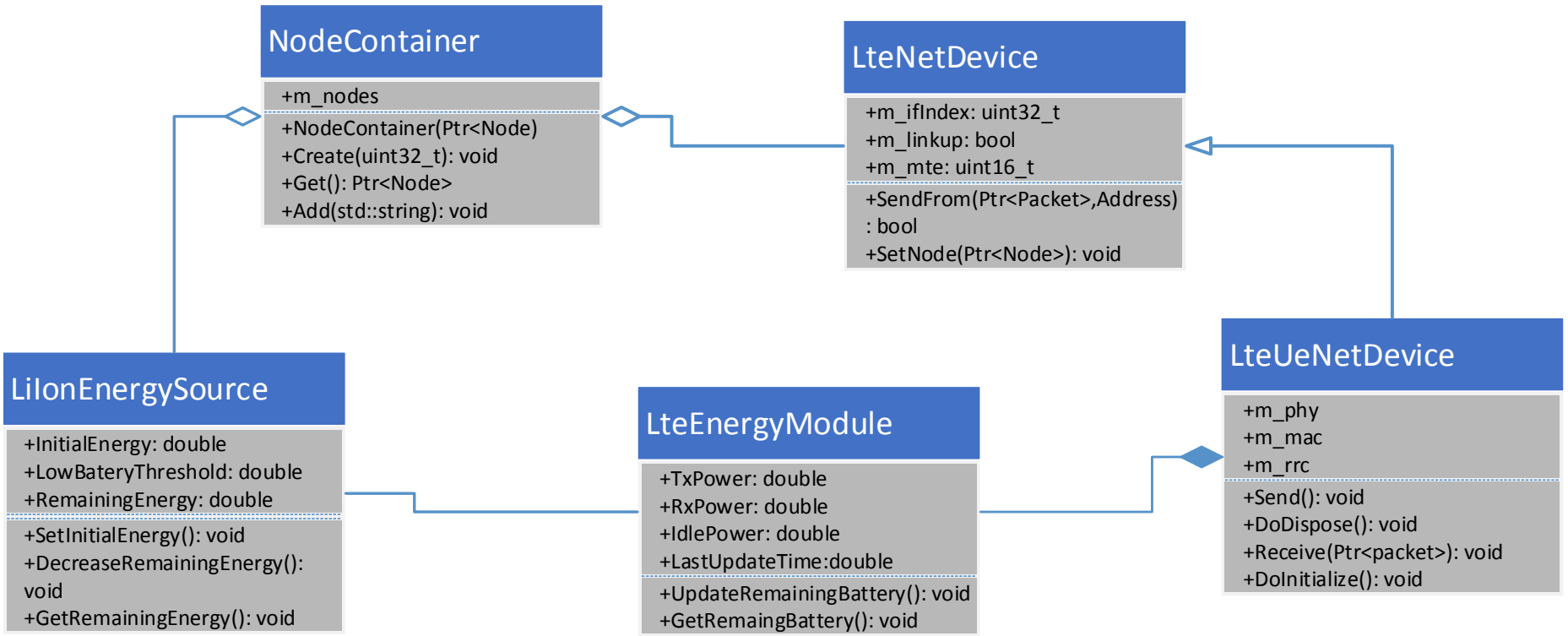
Battery Module

1. A battery is associated with each UE and energy expenditure module controls its discharging, which is done based on power consumption.
2. A Lithium-Ion energy source is used with initial energy for every UE as 37800 J (2100 mAh - a typical smartphone battery capacity).
3. Discharge of battery is controlled by energy expenditure module based on UE's activity.
4. For every state viz., Transmission, Reception, RRC connected and RRC Idle, the power dissipated is reduced from the power source.
5. Callbacks from energy expenditure module of a UE to their corresponding batteries notify the value of power spent in each trigger.

Table : Power spent in different states by LTE UE

State	Notation	Power (Watt)
IDLE (m_{idle})	P_{idle}	0.5
CONNECTED (m_{con})	P_{con}	1.53
ONLY RECEPTION (m_{Rx})	P_{Rx}	0.42
ONLY TRANSMISSION (m_{Tx})	P_{Tx}	0.55
TRANSMISSION AND RECEPTION (m_{Rx+Tx})	P_{Rx+Tx}	0.16
TWO CODE WORD (m_{2cw})	P_{2cw}	0.07

Class Diagram for LTE Energy Module in NS3



Simulation Parameters

Parameter	Scenario I	Scenario II	Scenario III
Simulation Time	300s	200s	200s
LTE Mode	FDD	FDD	FDD
Bandwidth	10 MHz	10 MHz	10 MHz
UE mobility model	Const Position	Const Position	RandWalk 2D
LTE MAC	MT	PF, RR, MT	PF
Inter packet interval	1,2,5 msec	10 msec	10 msec
No. of eNB, UE	1, 1	8, 80	8, 80
Tx power (eNB)	30 dBm	30 dBm	30 dBm
UE speed	-	-	3,14,27 m/s
HO algorithms	-	-	A2-A4 RSRQ A3-RSRP
Application type	UDP	UDP	UDP
Packet size	1500 Bytes	1500 Bytes	1500 Bytes

Scenario I : Single eNB and Single UE

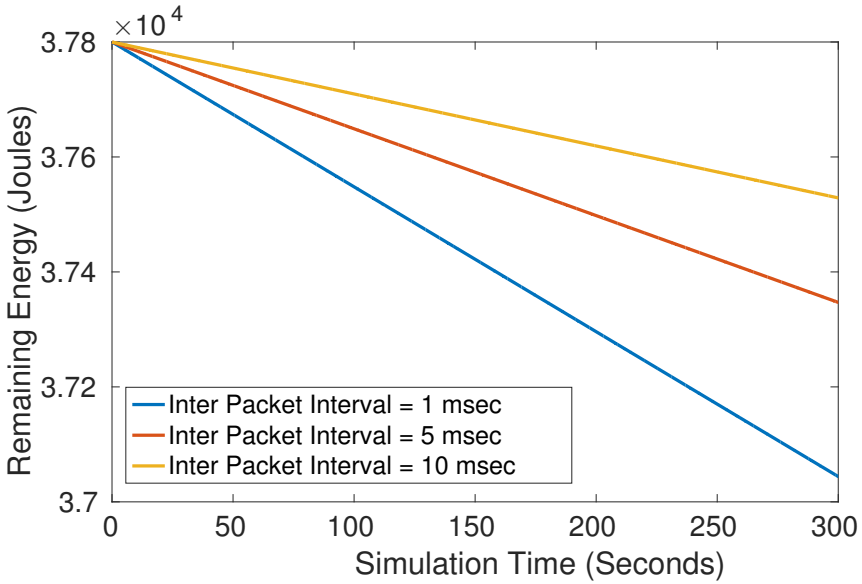


Figure : Remaining energy while downloading

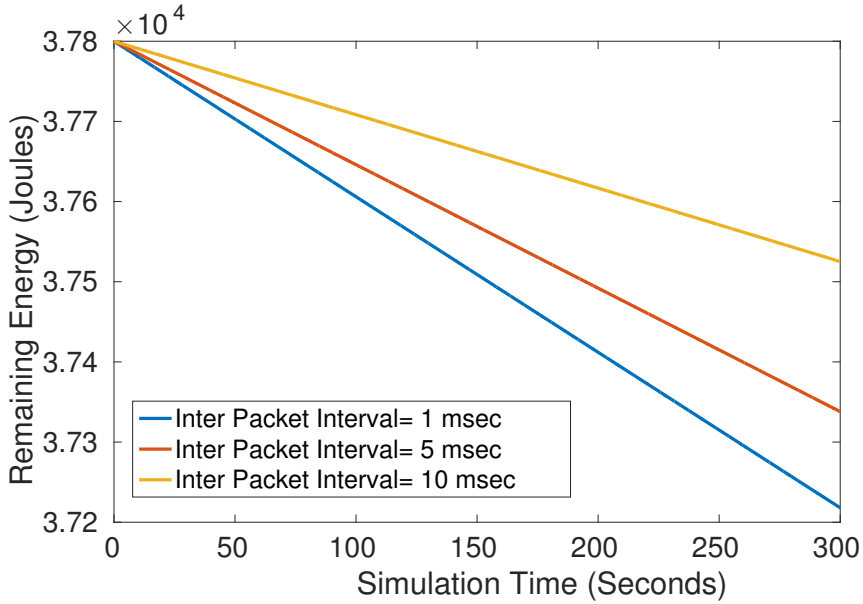


Figure : Remaining energy while uploading

Rate of reduction in power level

Downloading at higher rate involves high power expenditure.
Downloading consumes less power than uploading.

Scenario II : LTE MAC scheduler Power Profile

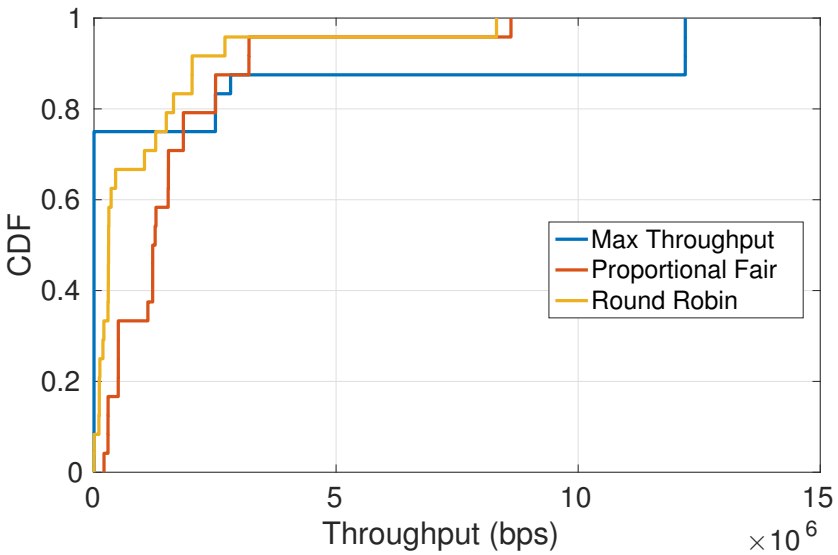


Figure : CDF of user throughput

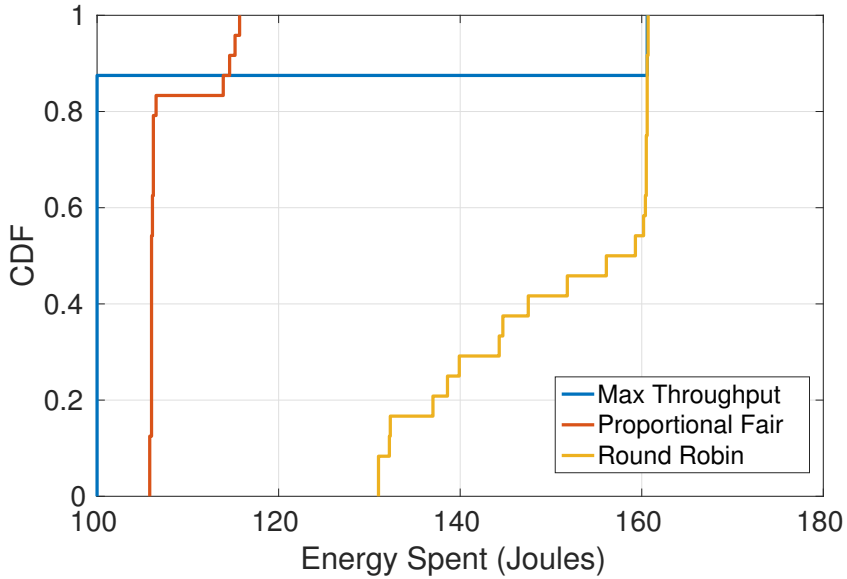


Figure : CDF of Energy spent

Power expenditure

- RR shares all the available resources among UEs which makes each UE to be kept awake in all TTI.
- Power spent in a network is efficiently regulated by PF scheduler
- MT does not serve more users which reflects in reduced power spent in the network

Scenario III : Handover across multiple cells

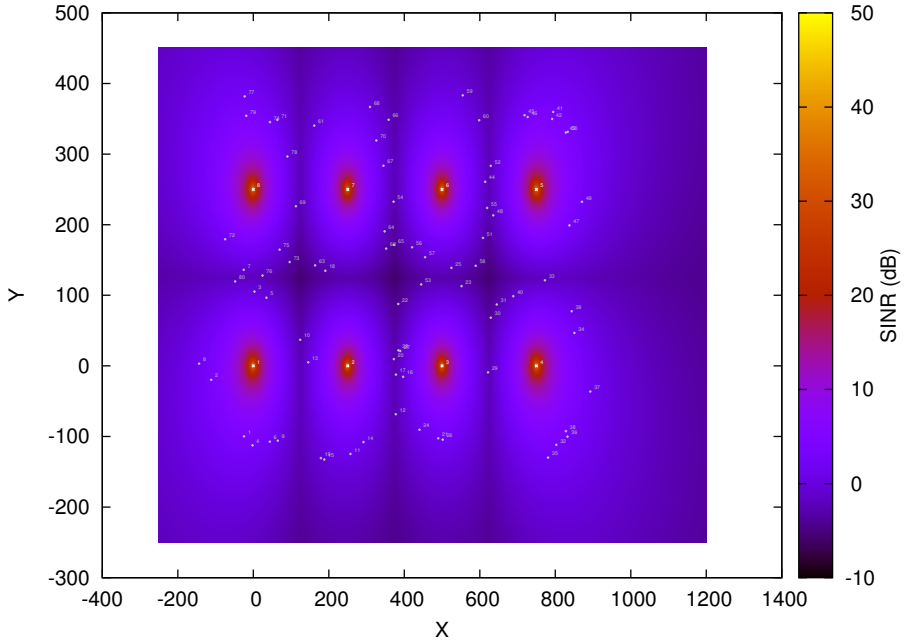


Figure : Simulation setup

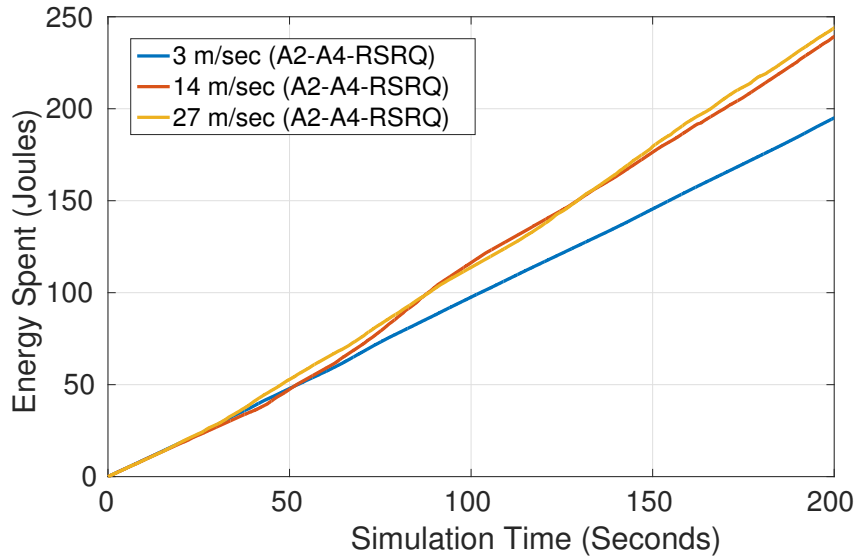


Figure : Energy spent during handovers

Handover across multiple cells

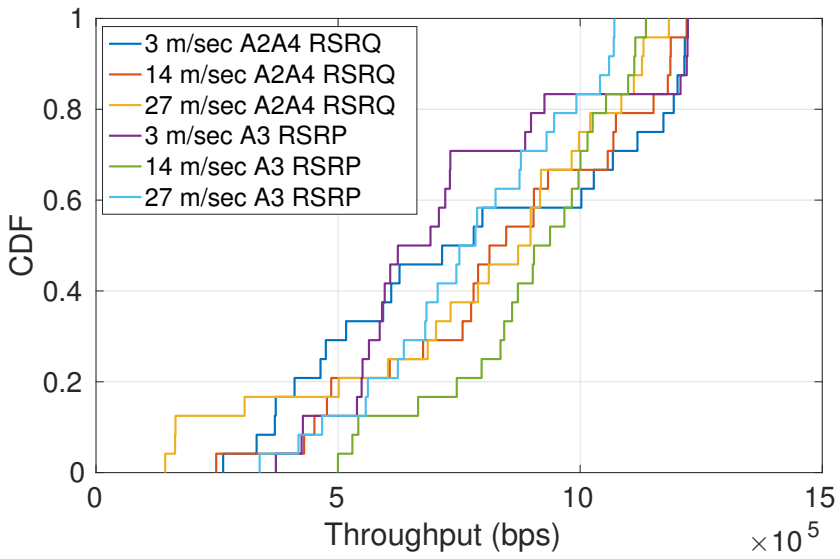


Figure : CDF of user throughput

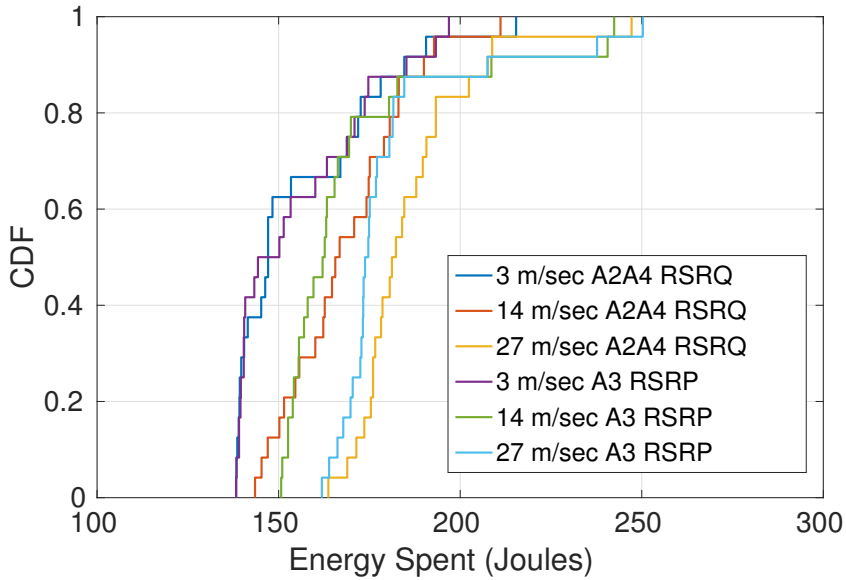


Figure : CDF of energy spent

Handover Energy Spent

- A3 RSRP is better compared to A2 RSRQ in making handover decisions, which leads to reduce energy spent by UE.
- As the UE moves faster, the energy dissipation rate is higher.

Conclusions

- Designed and developed LTE energy module for NS-3.
- Evaluated the module on various scenarios of static and mobile cases.
- LTE MAC scheduler power profiles are obtained.
- A3 RSRP is found to be power efficient as compared to A2 RSRQ.
- Made the source code open and deployed it in github [AB16] for public access.

Acknowledgement

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References I

- *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception.*
- Thomas Pasca Akilesh B, Arjun Anand, *LTE Energy Module NS3*, https://github.com/ThomasValerrianPasca/LTE_Energy_Module_NS3, 2016.
- A. R. Jensen, M. Lauridsen, P. Mogensen, T. B. SÃ¸rensen, and P. Jensen, *Lte ue power consumption model: For system level energy and performance optimization*, Vehicular Technology Conference (VTC Fall), 2012, pp. 1–5.

Queries

`https://github.com/ThomasValerrianPasca/LTE_Energy_Module_NS3.git`