Enabling **'Virtual Realistic Field Trials'** for Cellular Networks by Integrating **'Quadriga + Ns-3'**

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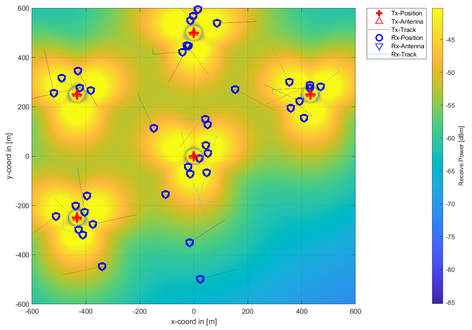
Why Simulate Cellular Networks?

- **Real world cellular networks** tend to be **complex** with lots of base stations, users & events and are based on **intricate standards** like **LTE/5G**. **Real LTE networks** operate at **sub-optimal configurations** as it is **hard to anticipate their behavior** for a **given real scenario**.
- Given the **complicated nature of cellular networks**, operators like T-Mobile, Verizon etc. wish to **resort to simulations** to find out what will happen in an LTE network run with a **given set of parameters** and **how to optimize** them.

Realistic Channel Measurements from Quadriga

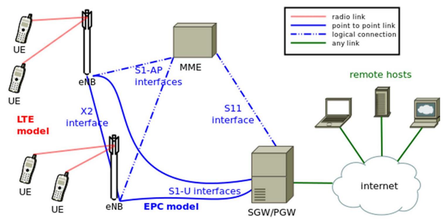


Quadriga
The Next Generation Radio Channel Model

- **Given scenario** has **fixed base stations & moving Users.**
- **Trials** represent **stochastic variants** of scenarios with **different seeds**.

- **Quadriga** is a MATLAB script that enables us to **generate realistic channel measurements** close to what one would **actually obtain in the field**.

LTE-EPC Simulator based on ns-3

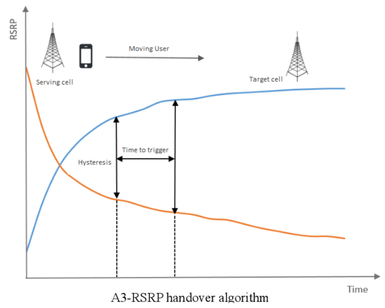


LENA
LTE-EPC Network simulAtor

- **LENA simulator** in **ns-3** is a **discrete event simulator** in C++ that **approximates LTE networks & EPC-based internet networks** and **enables scalable simulations** for a given scenario & parameter configuration.
- This allows mobile network operators to **test out optimization algorithms** for their networks **before actual deployment** in the field.

Handovers in LTE Systems

- Cell phones would like to connect to the **base station with the highest received power** for achieving **best possible data rates**.
- A **moving user hands over** from one base station **(serving cell)** to another base station **(target cell)** when its **received power (RSRP)** becomes greater than that of the current base station by a **certain threshold (Hysteresis)** for a given amount of time **(Time To Trigger)**.



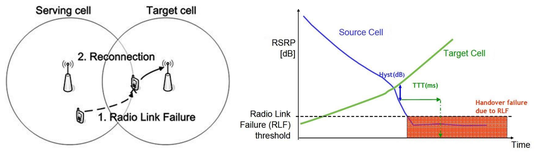
A3-RSRP handover algorithm

Handover Triggering Condition for the A3 Handover Algorithm in LTE

$RSRP_{target}(dB) - RSRP_{serving}(dB) >$ ***Hysteresis (dB)*** *for* ***Time To Trigger (s)***

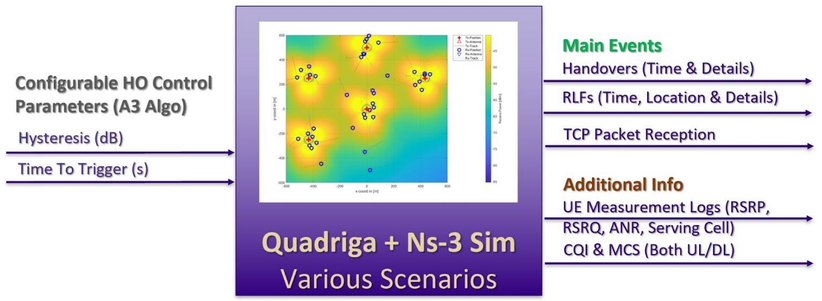
- **Hysteresis** and **Time To Trigger** are **HO control parameters** input to our simulation.
- **Incorrect HO parameters** can cause **unnecessary handovers** or **radio link failures**.

Radio Link Failures (RLFs)



- If **HO control parameters** are set incorrectly, **user can lose connection** with the serving cell before handover leading to **a large data loss**.

Black Box Model for Integrated Simulator



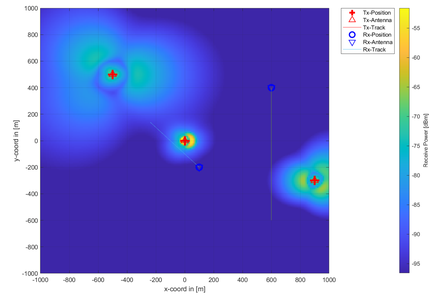
- We integrate **NS3 (great network simulator)** over **Quadriga (great channel simulator)**.
- **HO parameters** of **Hysteresis (dB)** & **Time To Trigger (s)** are **inputs** to simulation.

Results of One Sample Simulation Run

- **Large video file** is being transferred to 2 users on the **internet** over a **bad channel.**
- On running with **default ns-3 HO parameters**, we get,

1. Total throughput = ***844.522 kbps***
2. Data rate for user 0= ***404.358 kbps***
3. Data rate for user 1= ***440.163 kbps***

- User 0 faces **7 HOs & 1 RLF** while user 1 faces **4 HOs** and **no RLF**.

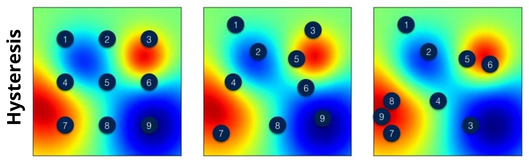


What HO Control Parameters to choose?

- **Real LTE networks** set HO control parameters to **sub-optimal values** (say ns-3 defaults of ***3 dB*** & ***256ms***) obtained from studies done for **specific scenarios.**
- Can we **optimize HO control parameters** for the **current scenario**?

HO Control Parameters	Possible Values According to the LTE Standard
Hysteresis	(0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10) in [dB]
Time To Trigger	(0 0.04 0.064 0.08 0.1 0.128 0.16 0.256 0.32 0.48 0.512 0.64 1.024 1.280 2.56 5.12) in [s]

Time To Trigger **figure for illustrative purpose*



- We can perform **grid search** over all points of the grid, **random search** over a subset of points or **adaptive selection** in an informed manner to optimize these values.
- **Searching over HO control parameters** in the **LTE standard** allows us to obtain **gains** of **around 20%** in total throughput and **about 30%** for non-standard values.
- We can also **predict the total throughput** at a **given operating point** for a network.

Future Work, References, and Acknowledgments

- Performance of **A/B testing algorithms** across various trials and scenarios.
- **Network policy** based on **deep reinforcement learning algorithms** for **intensely stochastic** LTE network simulations with randomly moving users.

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[1] S. Jaeckel, L. Raschkowski, K. Börner and L. Thiele, "QuaDRiGa: A 3-D Multicell Channel Model with Time Evolution for Enabling Virtual Field Trials", IEEE Transactions on Antennas Propagation, 2014.
[2] Nicola Baldo, Marco Miozzo, Manuel Requena-Esteso, Jaume Nin-Guerrero, "An open-source product-oriented LTE network simulator based on ns-3", MSWiM 2011: 293-298

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