Simulation Modelling for Design of Battlespace Communications System (Land) Networks

Centre for Defence Communications and Information Networking (CDCIN)

This work has been enabled through funding from the LAND2072 Project Office
Overview

1. Model Requirements
2. Model Design Considerations
3. Model Design Assumptions & Constraints
4. Model Design Construct
5. Model Design Effects
6. Model Design Verification
7. Demonstration
8. Upcoming Features
In operation for 30 years undertaking academic and commercial telecommunications R&D
- Continuous relationship with Telstra (Tier 1 MNO) since 1987
- Working closely with DST-G since 2000, and Defence more broadly since 2006

Staff have over 150 years of experience, gained locally and in international academic and industry R&D labs
- 11 full-time research and development staff
- Plus casual part time staff members + several adjunct academic staff (ECMS)
- Supervise PhD and Masters students (who do not participate in commercial work)
Non-defence work
The image shows a graphical representation of network analytics, specifically a traffic and admission region chart for a node named PRUELM2. The chart displays various data points indicating network performance metrics such as Speech Erlangs and HSPA Erlangs. The node headroom is highlighted with a percentage (24%) and a note suggesting an expansion of more than 2 years. The image is labeled as UNCLASSIFIED.
First 3G iPhone impacts the Telstra network

Next iPhone

Even great technology Must be “fit for purpose”
Bringing advanced research skills to bear on improving:
- Robustness
- Reliability
- Effectiveness
- Efficiency and
- Security

Through application of international quality capabilities in
- Modelling, Measurement, Management (3Ms)

With technical expertise and experience across
- All network layers
- Wide range of civilian and defence technologies, and applications
1: Model Requirements

1.1 Build a model to answer the question:

- Can the BCS(L) support a specific application traffic profile?

1.1.1 Model the network

- Wired
- Wireless
- Subnets with markedly different behaviour
- Possibly several 1000 nodes

1.1.2 Model application traffic across and within the BCS(L)

- Delays, losses and bottlenecks
- Realistic routing of traffic.

1.2 Deliver a tool for CASG and Army use

1.3 Model a “snapshot” of the network performance in time

- No reflection of changes during an operation
2: Model Design Considerations

2.1 Wireless

• Realistic radio propagation.
• Realistic waveform behaviour, e.g. sharing radio resource.
• Realistic radio device models.

2.2 Application traffic behaviour

• Realistic sharing of network resources by traffic.
  ▪ “QADI” tool – Flow level analysis
  ▪ “Trickster” tool – Packet/Slot level analysis
• Realistic routing of traffic.
• Priority of traffic.
• Overheads incurred by traffic.

2.3 Ease of use of graphical tool

• Delivered a simulation tool driven by a web browser.
3.1 Application flows

- Defines the “scenario” of the model
  - Note: traffic scenario not agreed yet – future requirement

- Stream of data
- Origin/destination
  - Node or Node type
- Message size (bits)
- Data + overhead such as security protocols
- Message rate
- Priority
- Type: Voice, Video, Data
3.2 Network model

- Shortest path routing
- Route discovery overheads are not currently modelled
  - Plan to model as a simple fixed overhead
3.3 MAC model (radio resource sharing)

- LTE Cellular Networks
- Fixed links
  - HCLOS
  - Fibre
  - Satellite
    - FDMA
    - TDMA
- Tactical wireless
  - EPLRS
    - Share of resource based on number of nodes in the network
      - No dynamic re-prioritisation as scenario is static
    - Neighbourhood discovery overheads are currently modelled as reserved frames
3.3 MAC model (radio resource sharing)

- LTE – Long Term Evolution
  - 4G Cellular Mobile Technology
  - Carrier Frequencies (including)
    - 700, 1800, 2300 MHz
  - Bandwidth
    - 1.4, 3, 5, 10, 15, 20 MHz
- SINR versus Data Rates
- Wireless Technologies
  - SISO
  - MIMO
    - 2x2
    - 4x4
3.3 MAC model (radio resource sharing)

- LTE MAC
  - TDMA – 1000 TTIs per second
  - Set of users scheduled each TTI
    - Round Robin
3.4 Radio model

- Radio propagation
  - Free-space loss, SATCOM delays
  - Terrain
    - Reflections
    - Clutter
    - Diffraction
    - Land-use
    - Clutter Loss
  - Urban – Hata
- Antenna Models
  - Directional
  - Sectorised
- Jamming Models
  - Directional
3.4 Radio model

- Waveforms
  - Frequency
  - Modulation
  - Bit error rate
- Radio devices
  - Transmit power
  - Sensitivity
- No fading or mobility, as network is a “snapshot” only
3.4 Radio Model

We have selected Canberra as an UNCLASS location scenario.
3.4 Radio Model
Canberra, with terrain added to the scenario
3.4 Radio Model

Canberra: LTE site artificially deployed on top of Parliament House

- 1.8 Ghz frequency band, 20 Mhz bandwidth
- Tower is 20 metres high
- Each sector has 40 Watts power
- The sectors have a maximum gain of 7 dBi
- The user equipment antennas are assumed at 2.0 metres
- Land use model is grassland – apart from the Urban model
- Up to 64 QAM and so about 6 symbols per Hz.
- All scheduling is Round Robin.

Propagation losses are a combination of
- Free space
- Clutter loss (land use model)
- Diffraction over objects (hills)
3.4 Radio Model

Canberra: maximum achievable data rates with omnidirectional antenna
3.4 Radio Model

Canberra: 3 & 6 Sectorised Antenna – no terrain effects
3.4 Radio Model

Canberra: 3 & 6 Sectorised Antenna – terrain effects added
3.4 Radio Model

Canberra: Directional jammer propagation pattern
3.4 Radio Model

Canberra: 3 & 6 Sectorised Antenna – terrain & jammer effects
3.4 Radio Model
Canberra: 3 Sector Antenna – now assuming 30m tall urban environment
3.4 Radio Model
Canberra: High power omnidirectional antenna – terrain & jammer effects
3.4 Radio Model
Canberra: Random users connected to an eNodeB
3.4 Radio Model

Canberra: Unit mobility – no terrain or jammer effects modelled
3.4 Radio Model
Canberra: Unit mobility – terrain effects modelled
3.4 Radio Model

Canberra: Unit mobility – terrain & jammer effects modelled
3.4 Radio Model

Comparing the 3 different mobility scenarios

User Rates – Different Scenarios

[Graph showing user rates across different scenarios]
3.5 Model Inputs & Outputs

**inputs**

- Flows
- Nodes (Fixed links, Wireless links)
- Applications
- Operational scenario
- Radio environment

**outputs**

- Offered traffic
- Delay
- Carried traffic
- Traffic lost
- Slowest link speed
- Node In/Out Traffic
- Traffic lost at node
3.5 Model Inputs & Outputs

Model inputs: three simple comma-separated .csv files:

- **Subnets**
  - Satellite / tactical mesh / fixed / LTE
  - Rate

- **Nodes**
  - Location, name, position in hierarchy
  - Type – Base station, User, Jammer

- **Flows**
  - Source, destination node or node type
  - Priority
  - Rate
  - Application Type: Voice, Video, Data
  - Protocol Type: UDP, TCP
4: Model Design Construct

JAVA APPLICATION

APP layer model (QADI)
- Flow based
- Throughput
- Delays
- Priorities
- TCP flow analysis

NET layer
- routing

MAC layer
- Dynamic TDMA
- Fixed links

PHY layer

JAVA

GUI

Web browser
PABLO web app
Agile framework
web2py web server
Python + modules

Text editor

Scenario
- Nodes
- Flows

Outputs for Analysis

execute

edit

used by

stores
5: Model Design Effects

5.1 Traffic delays
   • Determine whether network applications would function properly.

5.2 Traffic losses
   • Determine whether network applications would function properly.

5.3 Network bottlenecks
   • Can provide feedback on network or subnet (e.g. gateway) design.
     ▪ E.g. add relays

5.4 Delays/losses vs traffic types (voice, video, data)
   • Can provide feedback on prioritisation policies
6: Model Design Verification

6.1 Fixed side of network (BTN)
   • Used BTN reference design as used by various BCS(L) stakeholders.
   • 47 nodes

6.2 Tactical side of network (TCN)
   • Used part of brigade-level TCN model as supplied by DSTG Group.
   • 214 nodes
   • EPLRS bearer models verified in previous work
Software Tool Demonstration

PABLO web app delivered to CASG
BCS(L) Model Demonstration

7.1 Web Interface
**BCS(L) Model Demonstration**

**7.1 Web Interface**

- **View**

![Web Interface Screenshot]

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BCS(L) Model Demonstration

7.1 Web Interface
BCS(L) Model Demonstration

7.1 Web Interface
BCS(L) Model Demonstration

7.1 Web Interface

Subnets
## BCS(L) Model Demonstration

### 7.1 Web Interface – Network Summary

![Web Interface Image]

#### Nodes

**Nodes Table**

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**Legend:**
- **Satellite:** Sat
- **Formation:** EVU
- **UNIT:**
- **HCLOSTrelay:** ESR
- **Networks:** BCSSL

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**UNCLASSIFIED**
BCS(L) Model Demonstration

7.1 Web Interface – Network Summary
BCS(L) Model Demonstration

7.1 Web Interface – Traffic Flow Analysis

Select traffic scenario

Select network
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7.1 Web Interface – Traffic Flow Analysis

Graph results

Bandwidth Available Per Path (bits/second)

Path name: 296->15.5
Origin: BCLCTC, edge (ID 296)
Destination: BzlC2OTM (ID 55)
Bandwidth available along path: 168,666 bits/second
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7.1 Web Interface – Traffic Flow Analysis
BCS(L) Model Demonstration

7.1 Web Interface – Traffic Flow Analysis

Network structure (zoomed)
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7.1 Web Interface – Traffic Flow Analysis

Can examine paths or flows
BCS(L) Model Demonstration

7.1 Web Interface – Traffic Flow Analysis

Can use bar chart, heatmap or boxplot (spread) graphs: zoom if useful
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7.1 Web Interface – Traffic Flow Analysis

Can examine capacities, delays or losses
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7.1 Web Interface – Traffic Flow Analysis

Capacity along paths
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7.1 Web Interface – Traffic Flow Analysis

Heatmap (all to all) of path capacities
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7.1 Web Interface – Traffic Flow Analysis

Boxplot (spread) of path capacities
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7.1 Web Interface – Traffic Flow Analysis

Can repeat all graph types for traffic delays…
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7.1 Web Interface – Traffic Flow Analysis

...and traffic loss
All graph types and metrics can be repeated for flows
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7.1 Web Interface – Traffic Flow Analysis

Run a new simulation
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7.1 Web Interface – Traffic Flow Analysis

Create custom traffic
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7.1 Web Interface – Traffic Flow Analysis

Scale all traffic to find network capacity
BSC(L) Model Demonstration

7.1 Web Interface – LTE Capabilities

Some LTE parameters exposed

[Image of a web interface showing LTE simulation results and parameters]
**BCS(L) Model Demonstration**

7.1 Web Interface – LTE Capabilities

- LTE path delays
- LTE carried traffic
8: Upcoming Features

Physical Layer

- Extra functionality and exposed through web interface
- Add More Urban Models
  - B-Walfisch
  - Ericsson 999
- Multiple Cell Interference model
- Mobility models
8: Upcoming Features

LTE Air Interface

- LTE Coverage Planning
- LTE Cell Selection
- LTE MAC
- TDMA – 1000 TTIs per second
- LTE Downlink Scheduling
  - Equal Rate
  - Maximum Rate
- LTE Uplink Scheduling
  - SC-FDMA
- LTE Control Channel
  - PDCCH, PUCCH
- LTE with Remote Radio Units (RRUs)
8: Upcoming Features
LTE Core Network

- Mobility Management Entity (MME)
  - MME interfaces: S1-MME, S3, S11, S6a
  - Distributed MME: Load Balancing, MME Selection and MME Pooling
- Backhaul modelling
  - Dark Fiber, Satellite, Microwave and Wi-Fi Tunnelled Direct Set Up
- PCRF, HSS, S-GW and P-GW