



# Modeling and Performance Analysis of Public Safety Wireless Networks

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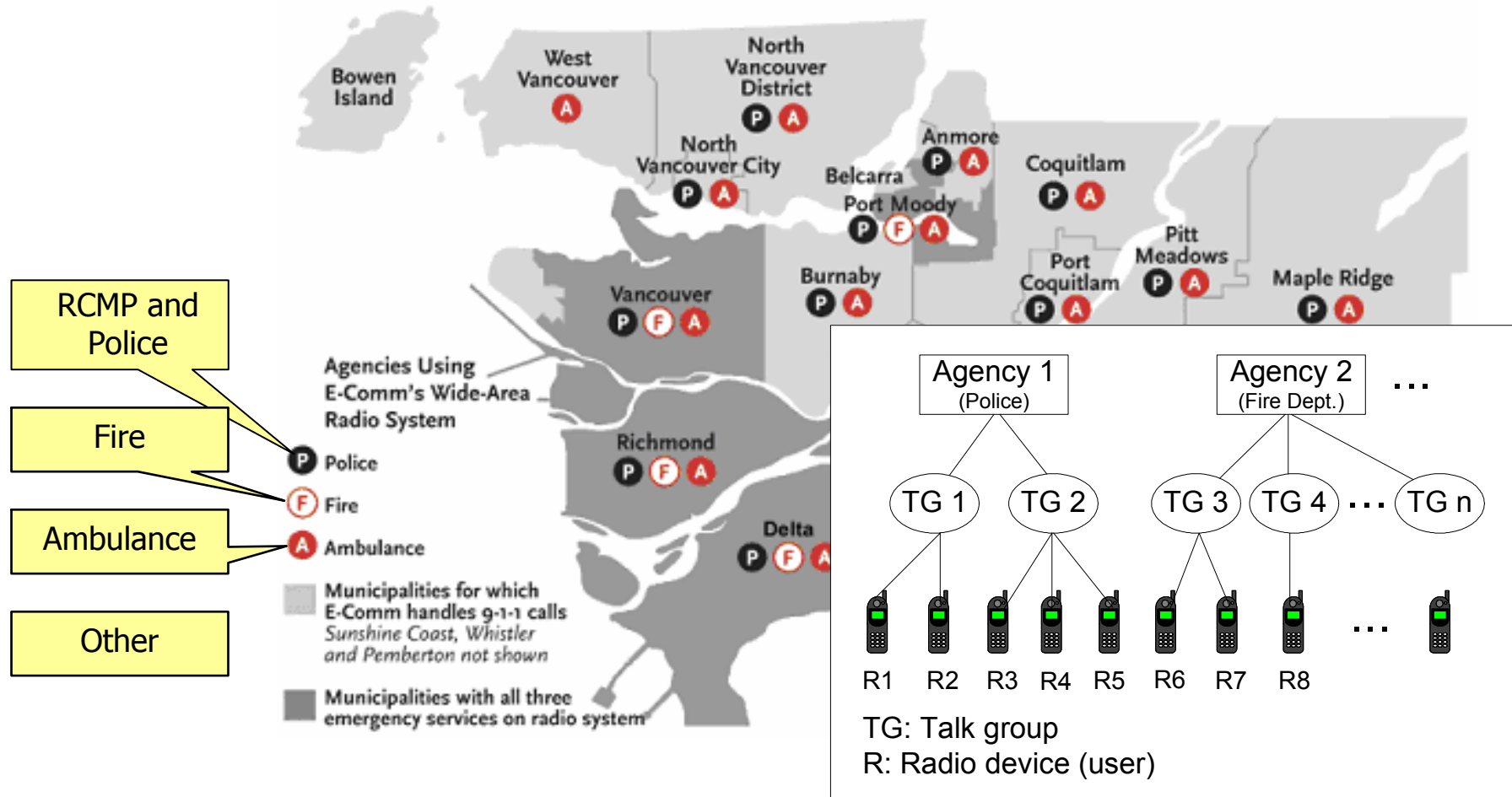
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# Road map

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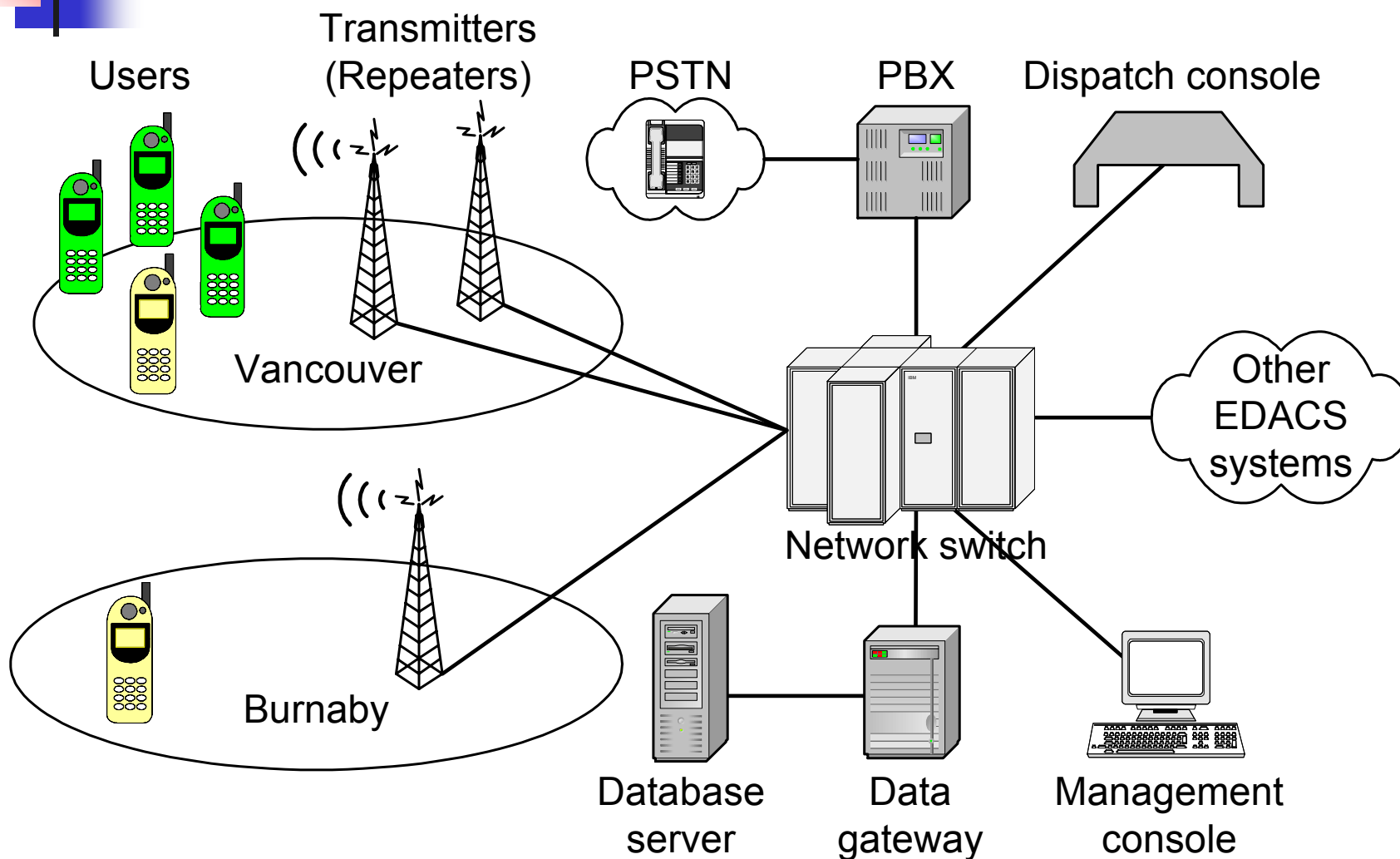
- E-Comm network
- WarnSim: a simulator for public safety wireless networks (PSWN)
- Traffic data analysis
- Traffic modeling
- Simulation and prediction
- Conclusions
- References

# E-Comm network coverage and user agencies





# E-Comm network architecture





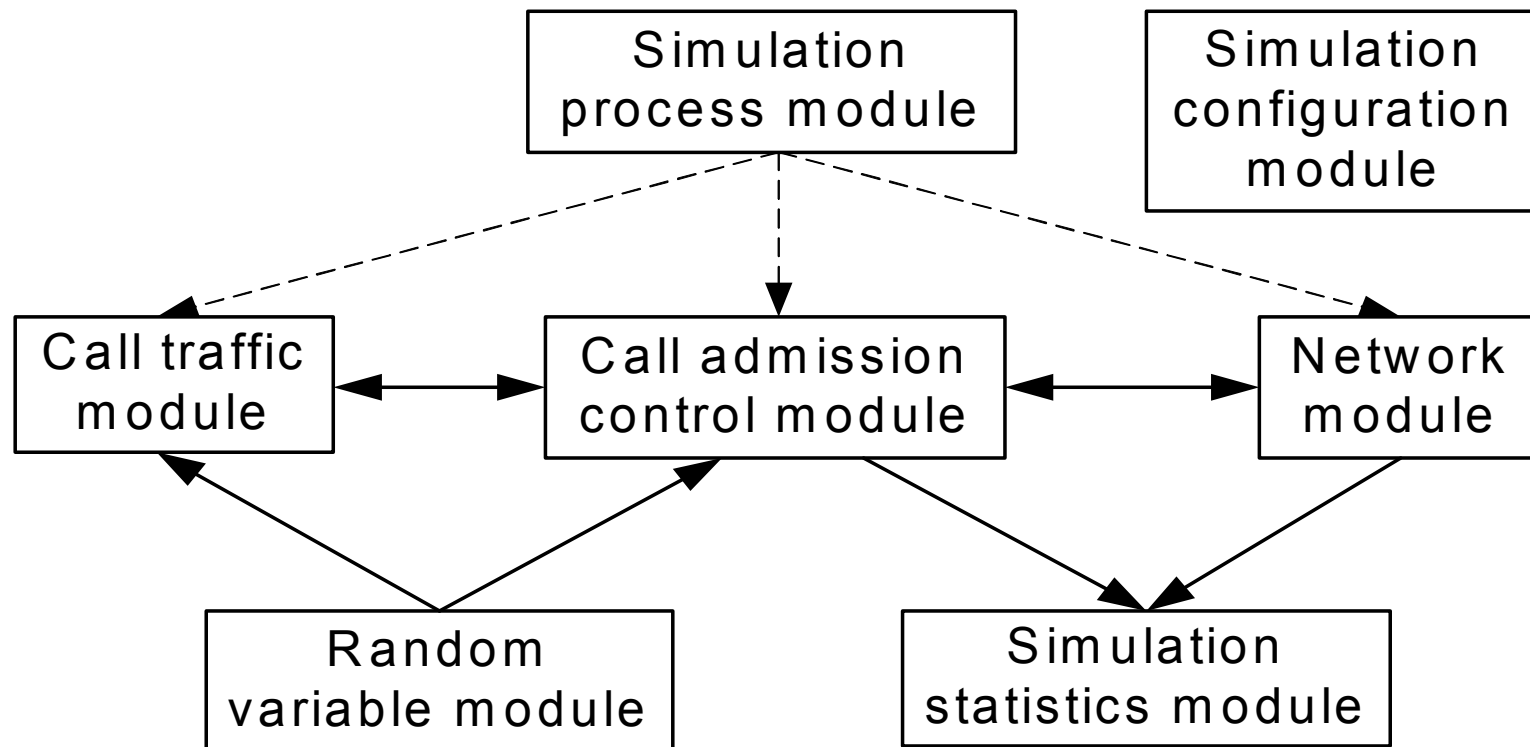
# WarnSim overview

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- Simulators such as OPNET, ns-2, and JSim are designed for packet-switched networks
- WarnSim is a simulator developed for circuit-switched networks, such as PSWN
- WarnSim:
  - publicly available simulator
    - <http://www.vannet.ca/warnsim>
  - effective, flexible, and easy to use
  - developed using Microsoft Visual C# .NET
  - operates on Windows platforms



# WarnSim: module diagram





# Traffic trace generator

The screenshot displays the WarnSim: Wide Area Radio Network Simulator interface. On the left, a 'Simulation steps' sidebar lists five steps: 1. Network topology, 2. Traffic trace (highlighted), 3. Sim parameter, 4. Sim run, and 5. Sim results. The main window shows a configuration for a traffic generator with the following parameters:

- ID: 1
- Name: Agency A
- Coverage: sample\_coverage.csv
- Start at: 0
- Call Holding: exponential
- Scale: 1000
- Call Int-Arr: lognormal
- Location: 0.55
- Scale: 8.05

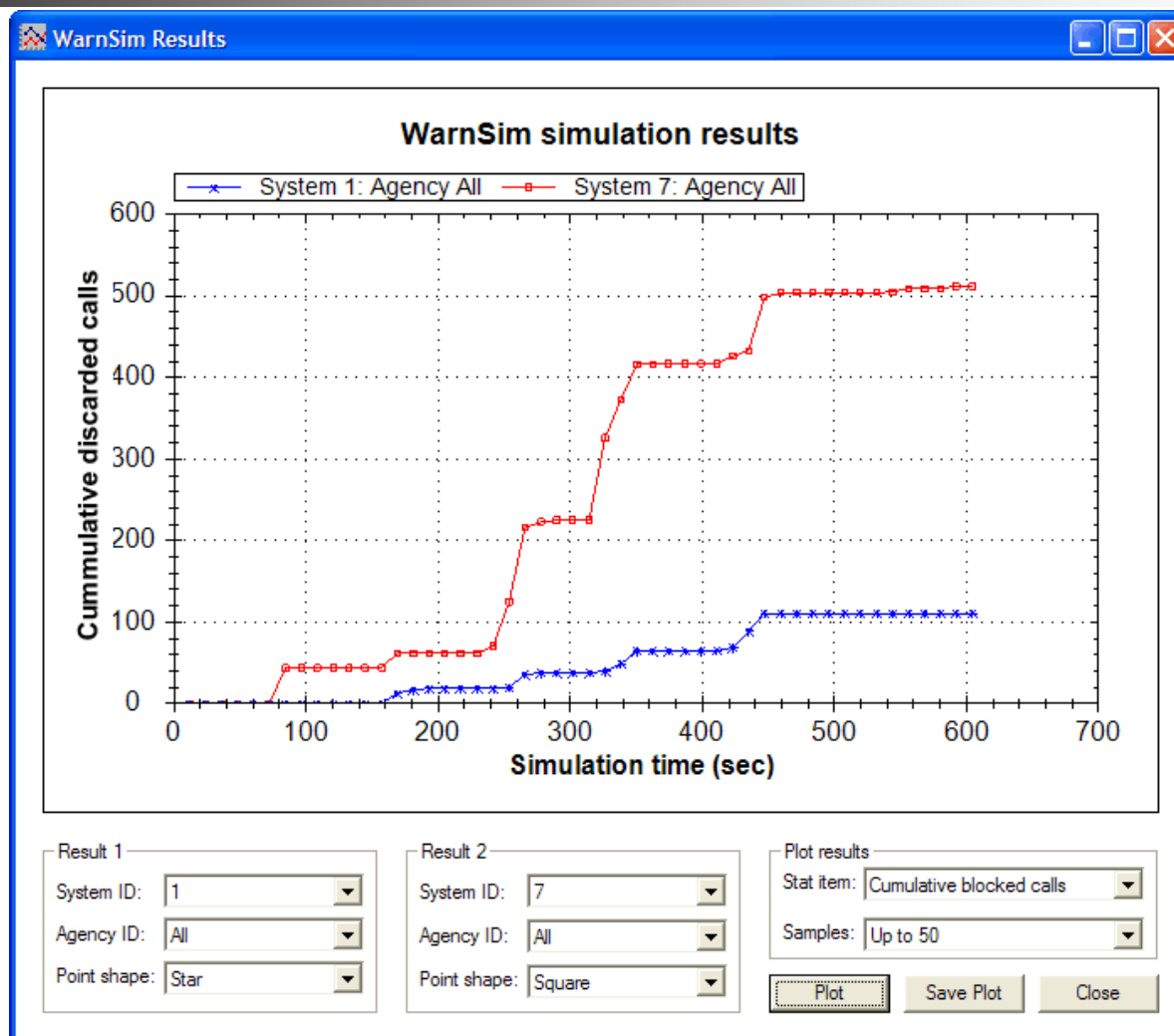
The 'Traffic Trace From Traffic Generator' dialog box is open, showing the following settings:

- Trace ID: 1
- Trace name: Agency A
- Call holding time: Distribution: exponential, Scale: 1000
- Call inter-arrival time: Distribution: lognormal, Location: (dropdown menu open showing options: exponential, gamma, loglogistic, lognormal, normal, uniform, weibull), Scale: (input field)
- Trace time offset: Start time: 0 (Unit: millisecond)
- Load predefined call coverage configuration: File name: E:\WamSim\sample\_coverage.csv

Buttons for 'OK' and 'Cancel' are visible at the bottom of the dialog. On the right side of the simulator window, there are controls for 'Call sources' (Generator, Import, Remove, Configure) and 'Traffic trace' (Save, Load).



# WarnSim results







# Traffic data

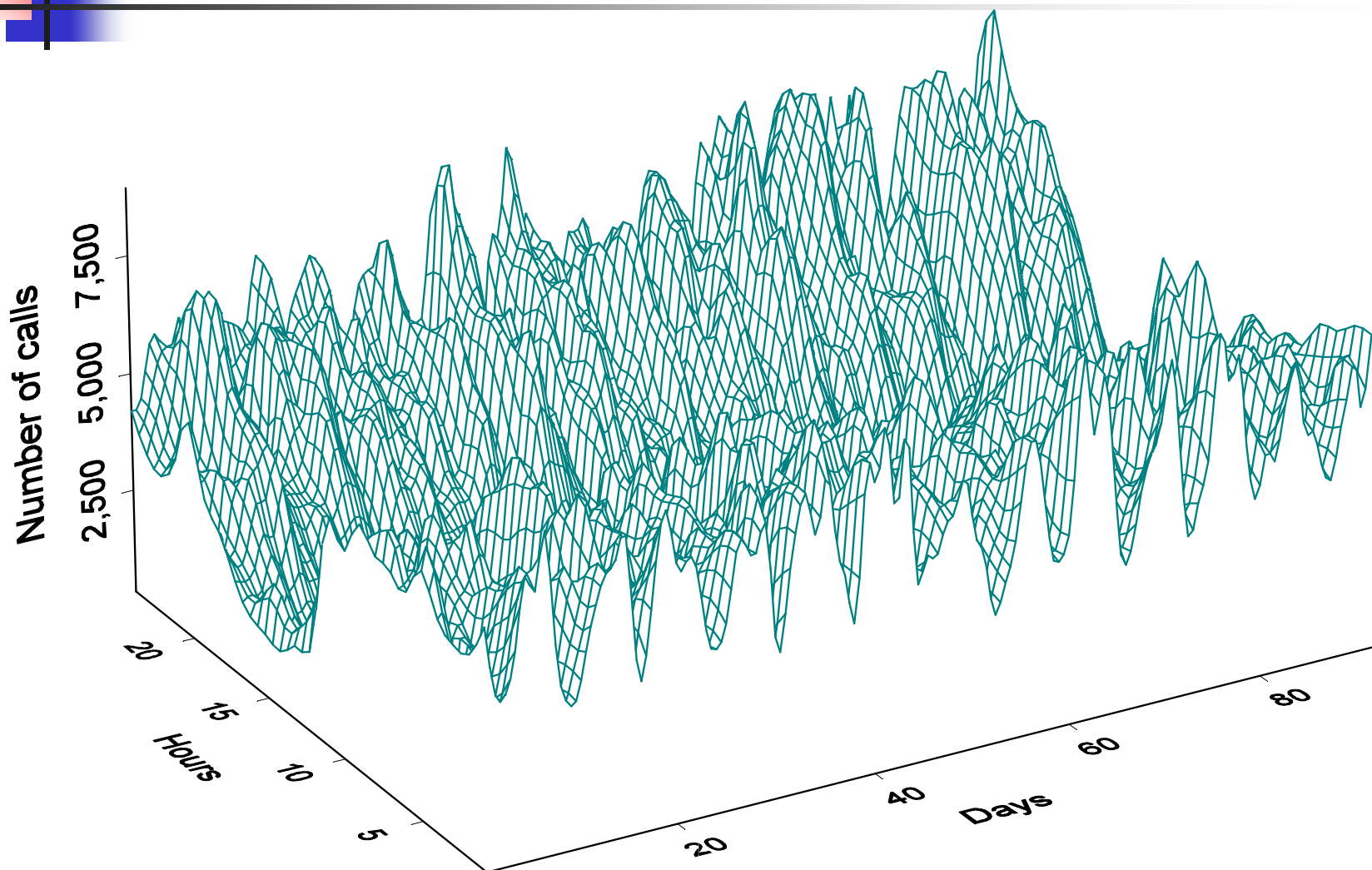
- 2 days of traffic data from 2001
- 28 days of traffic data from 2002
- 92 days of traffic data from 2003
- contain more than 10 million calls
- a sample record of the call traffic data:

Call arrival time	Duration (ms)	Caller agency
2003-05-01 00:00:09.620	1990	5

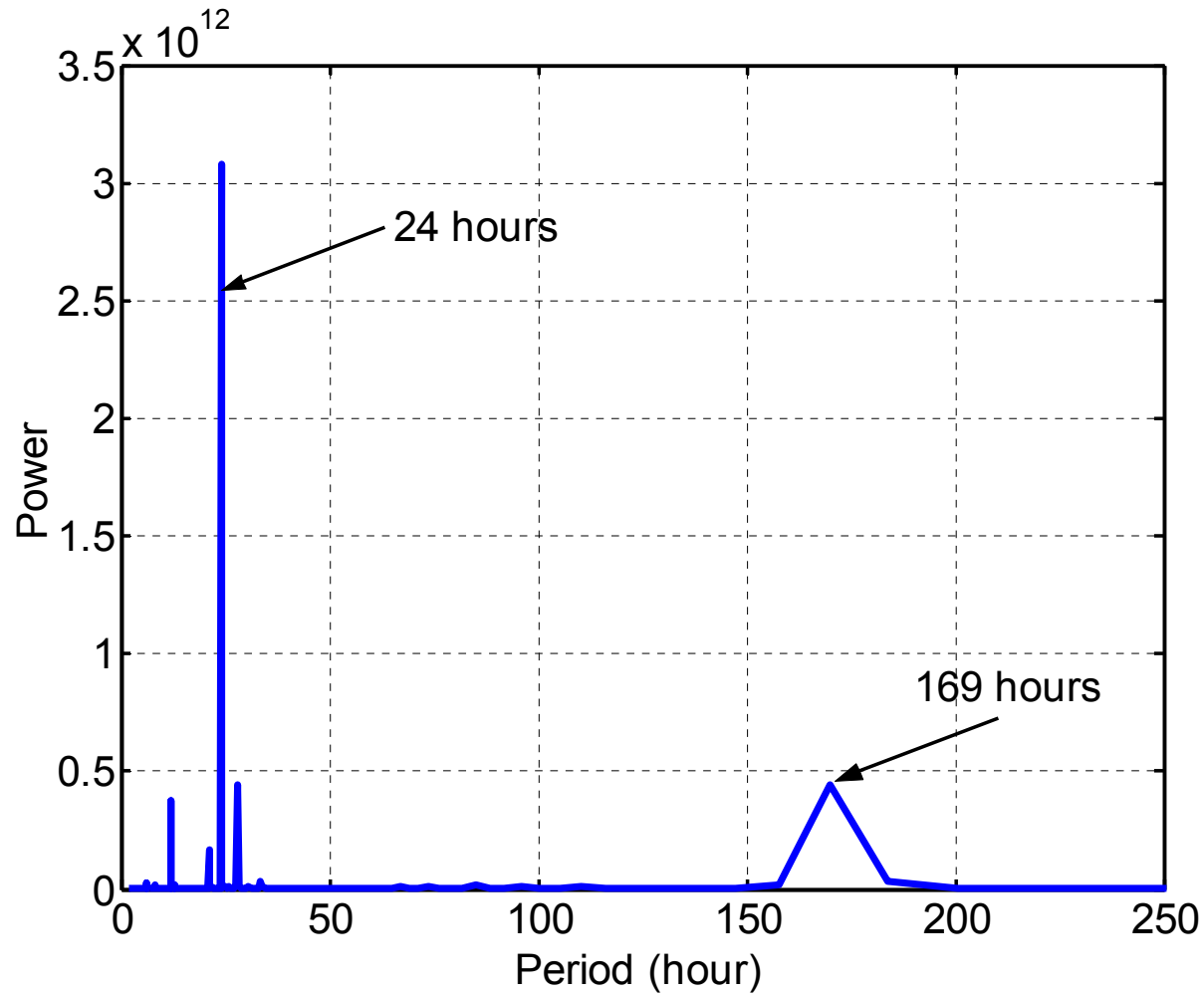
Caller	Callee	System ID	Channel no.
9999	1111	1, 7	3, 4



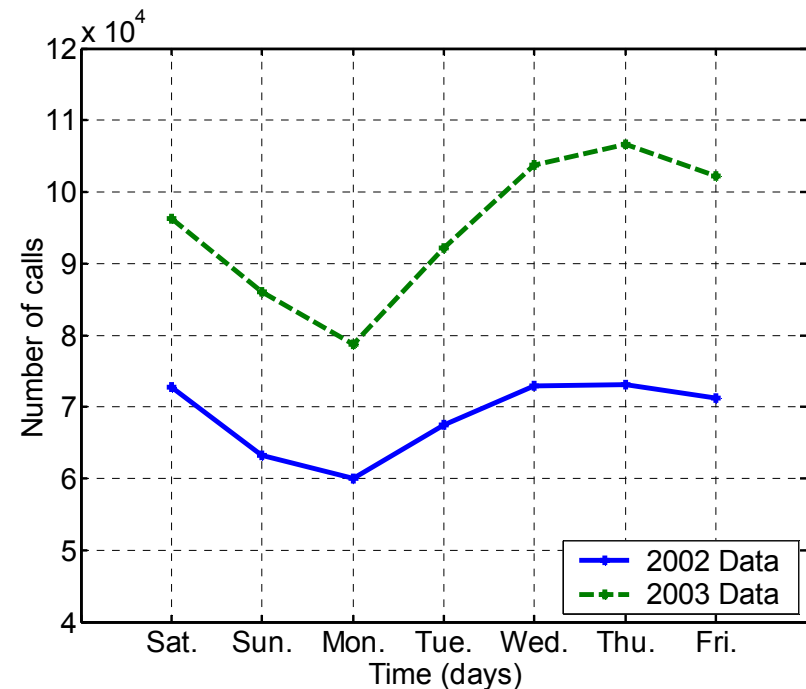
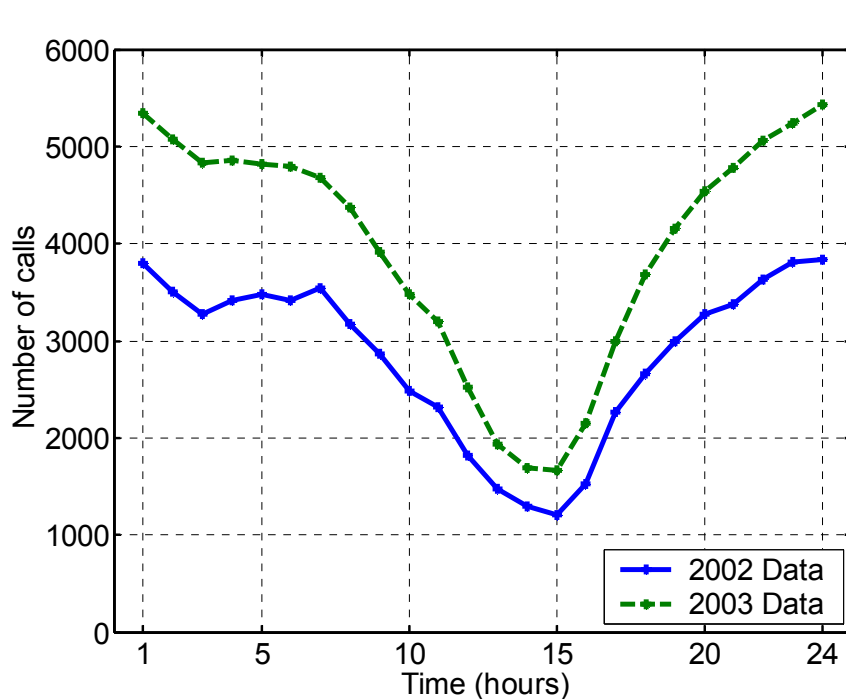
# Hourly call arrival rate in 2003



# Hourly call arrival rate in 2003: power spectrum



# Call arrival rate in 2002 and 2003: cyclic patterns



- the busiest hour is around midnight
- the busiest day is Thursday
- useful for scheduling periodical maintenance tasks



# Traffic modeling procedure

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- Modeling of traffic on user agency level
- Extract 500 data samples (call holding time/call inter-arrival time) from traffic data table
- Select a candidate distribution (exponential, lognormal, or gamma) and use Maximum Likelihood Estimation to estimate its parameters
- Use Kolmogorov-Smirnov goodness-of-fit (GoF) test to evaluate the candidate distribution



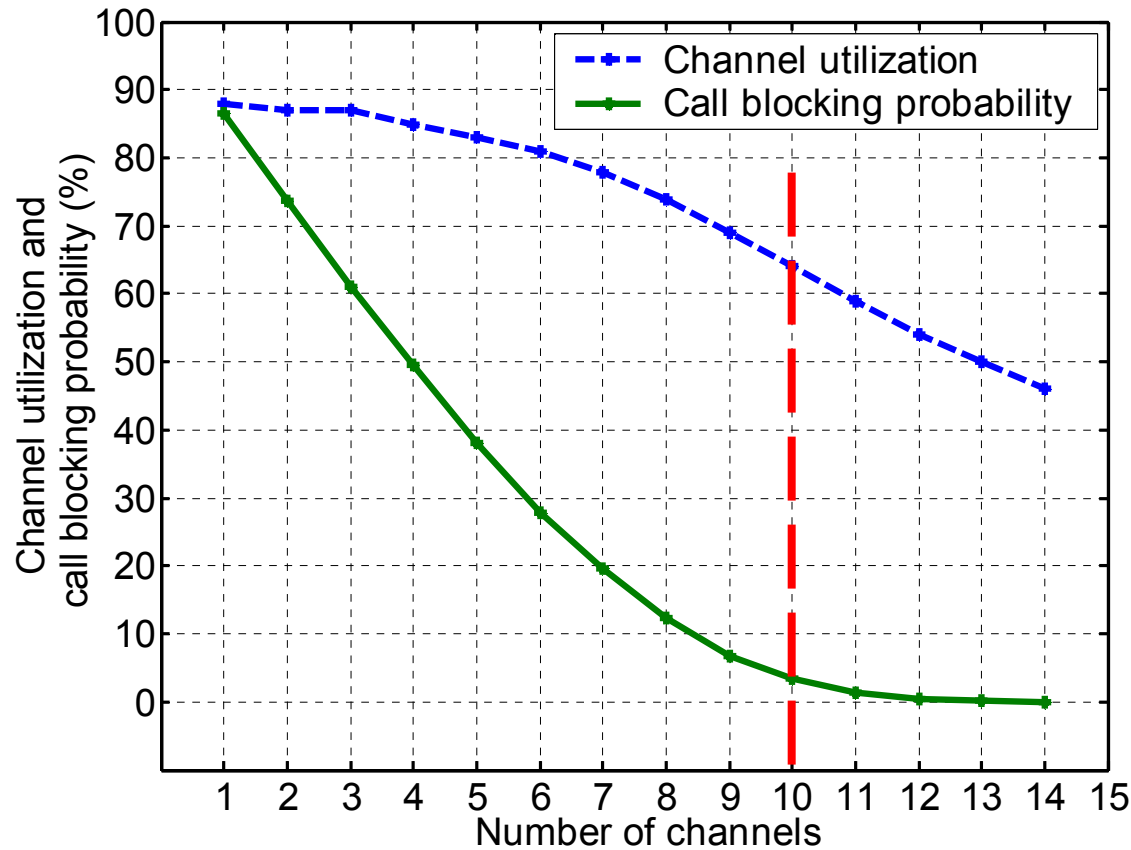
# Proposed call traffic model

- Use lognormal distribution to model call holding time at user agency level
- Use exponential distribution to model call inter-arrival time at user agency level
- Assume call coverage pattern remains constant

	Agency 2	Agency 5	Others
Call holding time	lognormal $\sigma = 8.05$ $\mu = 0.55$	lognormal $\sigma = 8.09$ $\mu = 0.73$	lognormal $\sigma = 7.88$ $\mu = 0.82$
Call inter-arrival time	exponential $\beta_1$	exponential $\beta_2$	exponential $\beta_3$

# Channels and Grade of Service

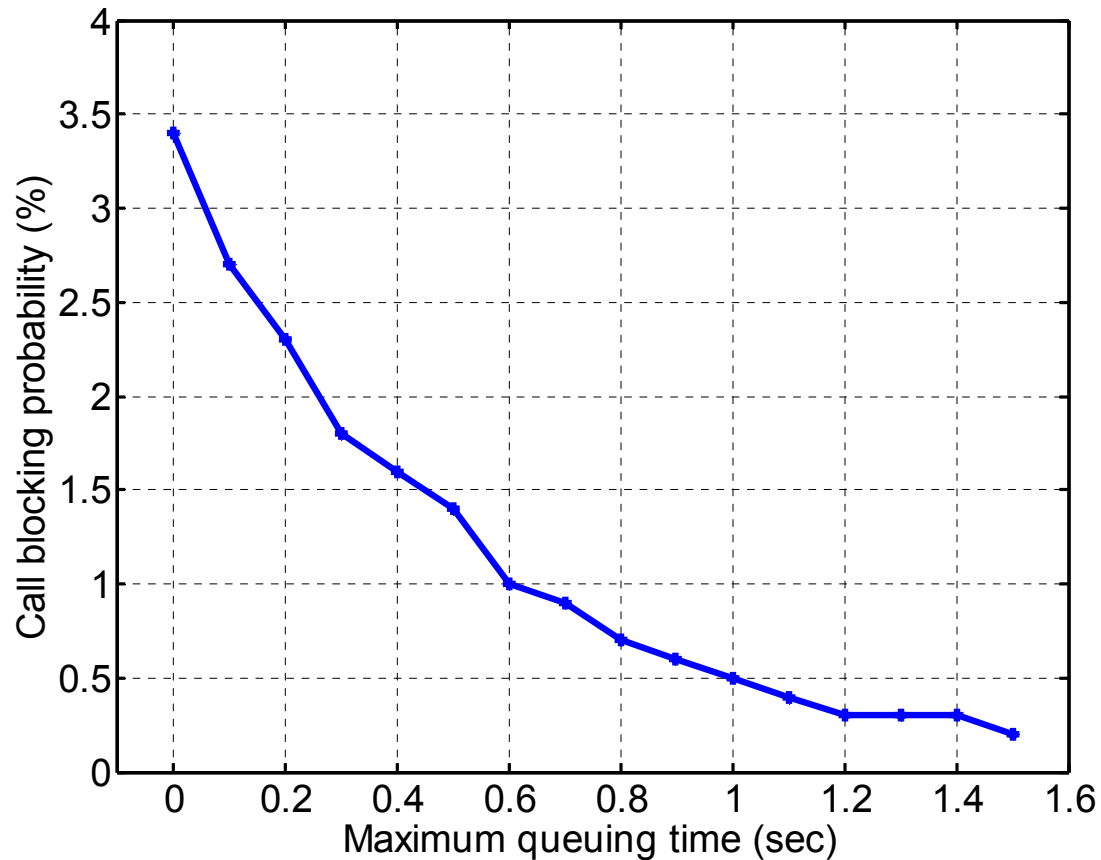
(busy hour 2003-05-15 2:00–3:00 am)



System ID	1	2	3	4	5	6	7	8	9	10	11
Channels	variable	7	4	5	3	7	8	4	7	6	3

# Queuing and Grade of Service

(busy hour 2003-05-15 2:00–3:00 am)



System ID	1	2	3	4	5	6	7	8	9	10	11
Channels	10	7	4	5	3	7	8	4	7	6	3





# Performance prediction

- Increased the number of calls made by Agency 5 by 100% from the busiest hour in 2003:
  - maximum queuing time is set to zero
  - parameters for WarnSim call traffic generator

	Agency 2	Agency 5	Others
Call holding time	lognormal $\sigma = 8.05$ $\mu = 0.55$	lognormal $\sigma = 8.09$ $\mu = 0.73$	lognormal $\sigma = 7.88$ $\mu = 0.82$
Call inter-arrival time	exponential $\beta = 1354$	exponential $\beta = 381$	exponential $\beta = 3480$



# Performance prediction

System ID	Number of channels	Original blocking probability (%)	Original channel utilization (%)	Predicted blocking probability (%)	Predicted channel utilization (%)
1	10	1.9 – 3.5	57 – 65	12.1 – 12.6	71 – 72
2	7	0.0 – 0.6	29 – 48	5.1 – 7.0	54 – 55
3	4	0.0	11 – 14	0.1 – 0.4	16 – 17
4	5	0.0 – 0.4	21 – 23	1.5 – 3.7	35 – 39
5	3	0.0	4 – 17	1.0 – 1.3	16 – 18
6	7	0.0 – 0.3	19 – 42	2.1 – 2.7	44 – 45
7	8	0.0 – 0.4	25 – 34	0.6 – 0.8	38 – 40
8	4	0.0	8 – 11	0.0 – 0.3	16 – 18
9	7	0.3 – 0.5	37 – 43	9.0 – 10.1	60 – 62
10	6	0.0	16 – 26	1.3 – 1.5	35 – 38
11	3	0.0	6 – 10	0.3 – 0.9	11 – 13



# Performance prediction

System ID	Number of channels	Original blocking probability (%)	Original channel utilization (%)	Predicted blocking probability (%)
1	10 + 4	1.9 – 3.5	57 – 65	< 3
2	7 + 2	0.0 – 0.6	29 – 48	< 3
3	4	0.0	11 – 14	0.1 – 0.4
4	5 + 1	0.0 – 0.4	21 – 23	< 3
5	3	0.0	4 – 17	1.0 – 1.3
6	7	0.0 – 0.3	19 – 42	2.1 – 2.7
7	8	0.0 – 0.4	25 – 34	0.6 – 0.8
8	4	0.0	8 – 11	0.0 – 0.3
9	7 + 3	0.3 – 0.5	37 – 43	< 3
10	6	0.0	16 – 26	1.3 – 1.5
11	3	0.0	6 – 10	0.3 – 0.9



# Conclusions

- Developed a new tool (WarnSim) for simulating Public Safety Wireless Networks
- Analyzed call traffic data and showed the cyclic patterns of the call arrival rate
- Proposed statistical models for call traffic on user agency level
  - call holding time: lognormal distribution
  - call inter-arrival time: exponential distribution
- Using WarnSim:
  - evaluated the E-Comm network performance
  - predicted the future performance of the E-Comm network

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# References

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- [7] N. Cackov, J. Song, B. Vujičić, S. Vujičić, and Lj. Trajković, "Performance analysis of a public safety wireless network: a simulation approach," *Simulation: Transactions of The Society for Modeling and Simulation International*, submitted for publication.

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Thank you

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Questions?

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