Modeling and Performance Analysis of Public Safety Wireless Networks

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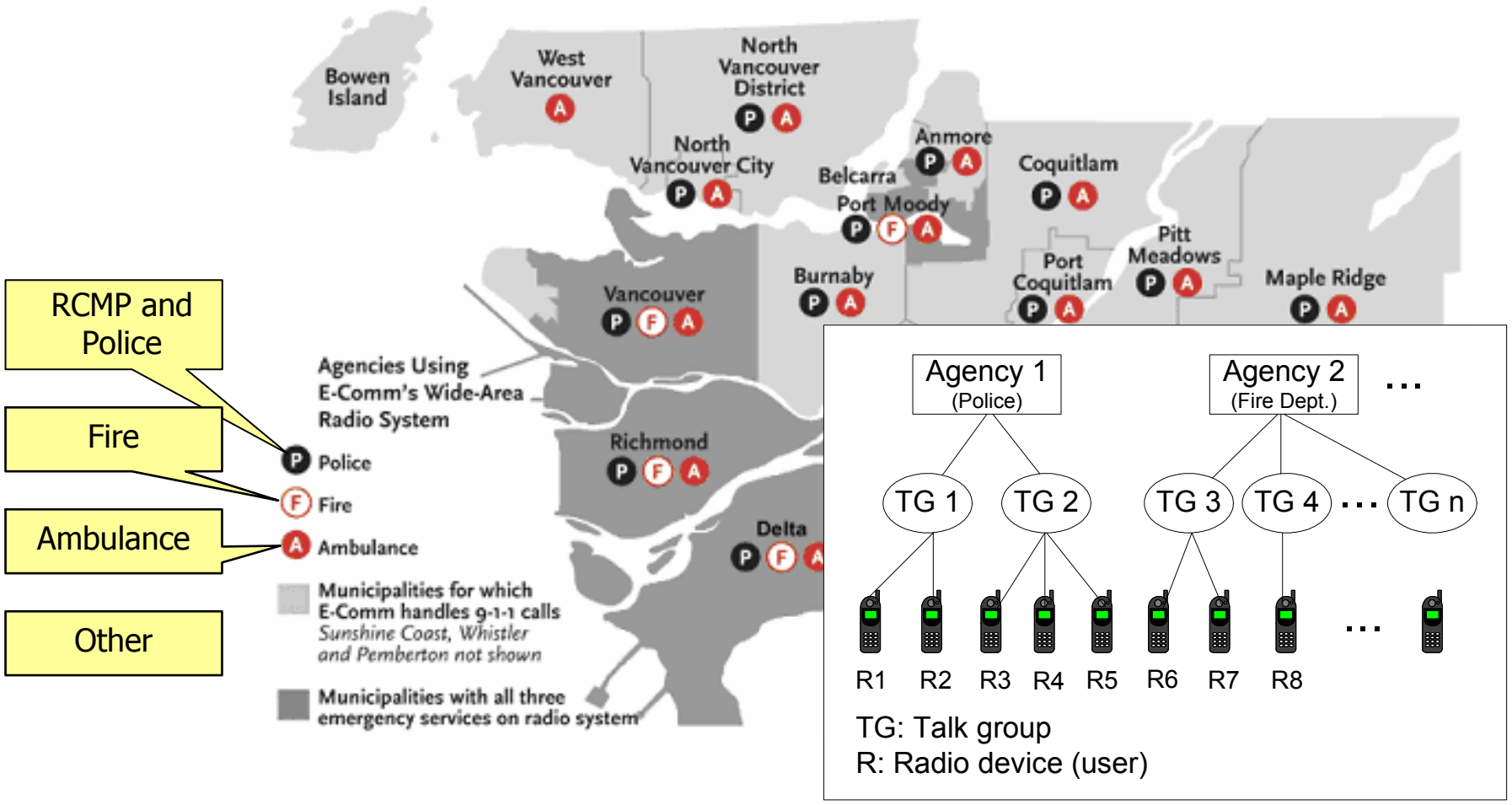
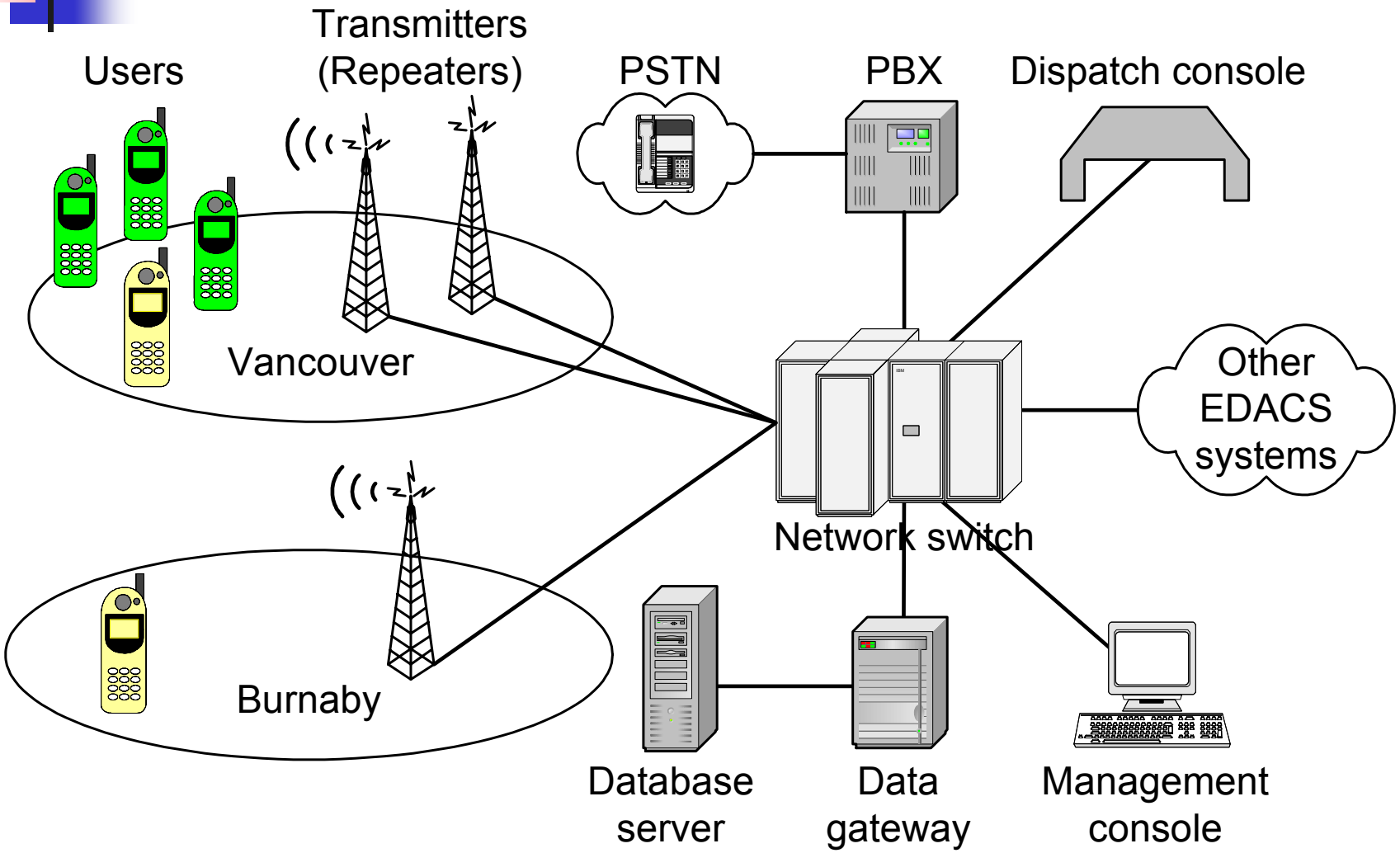
Road map

- 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



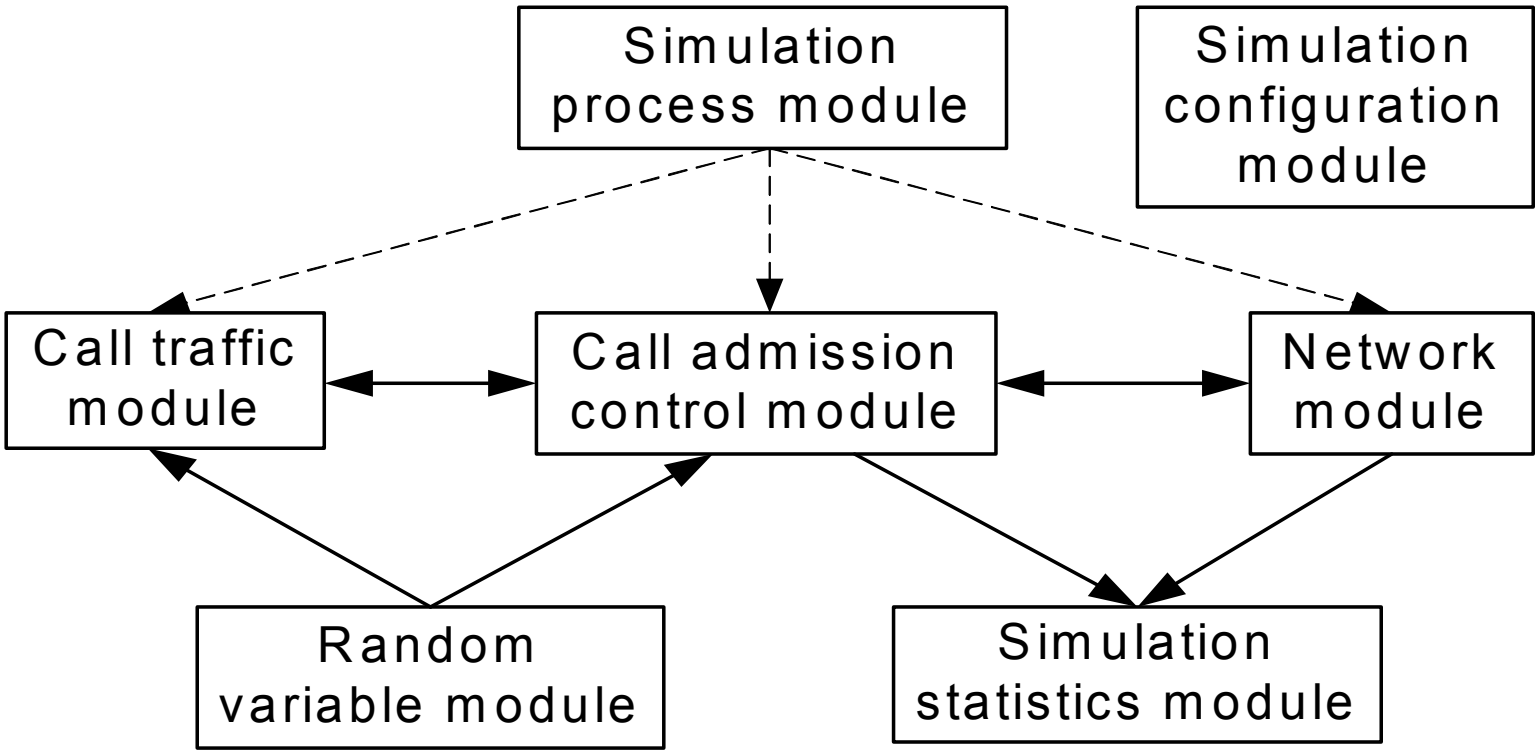
E-Comm network architecture



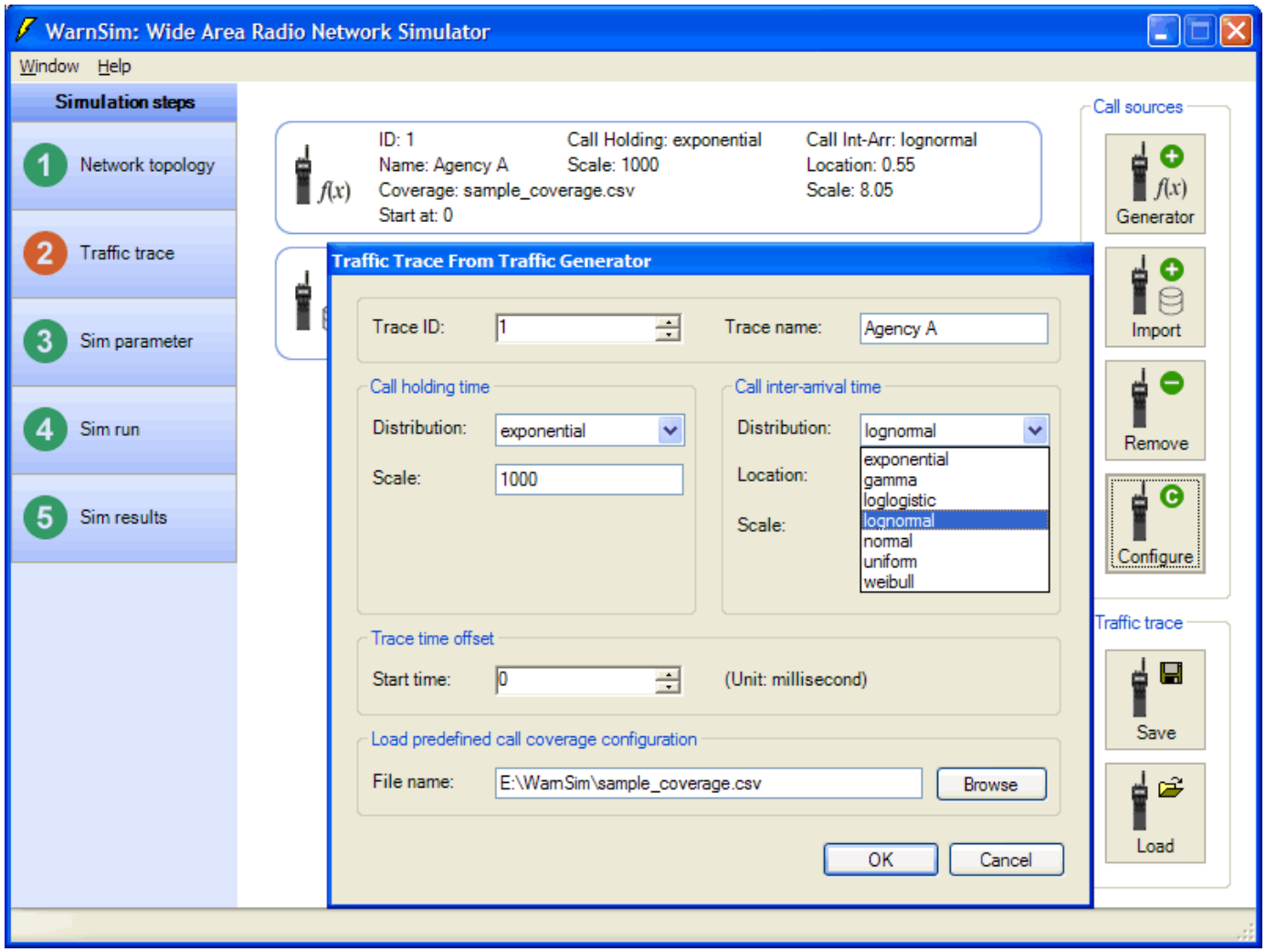
WarnSim overview

- 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

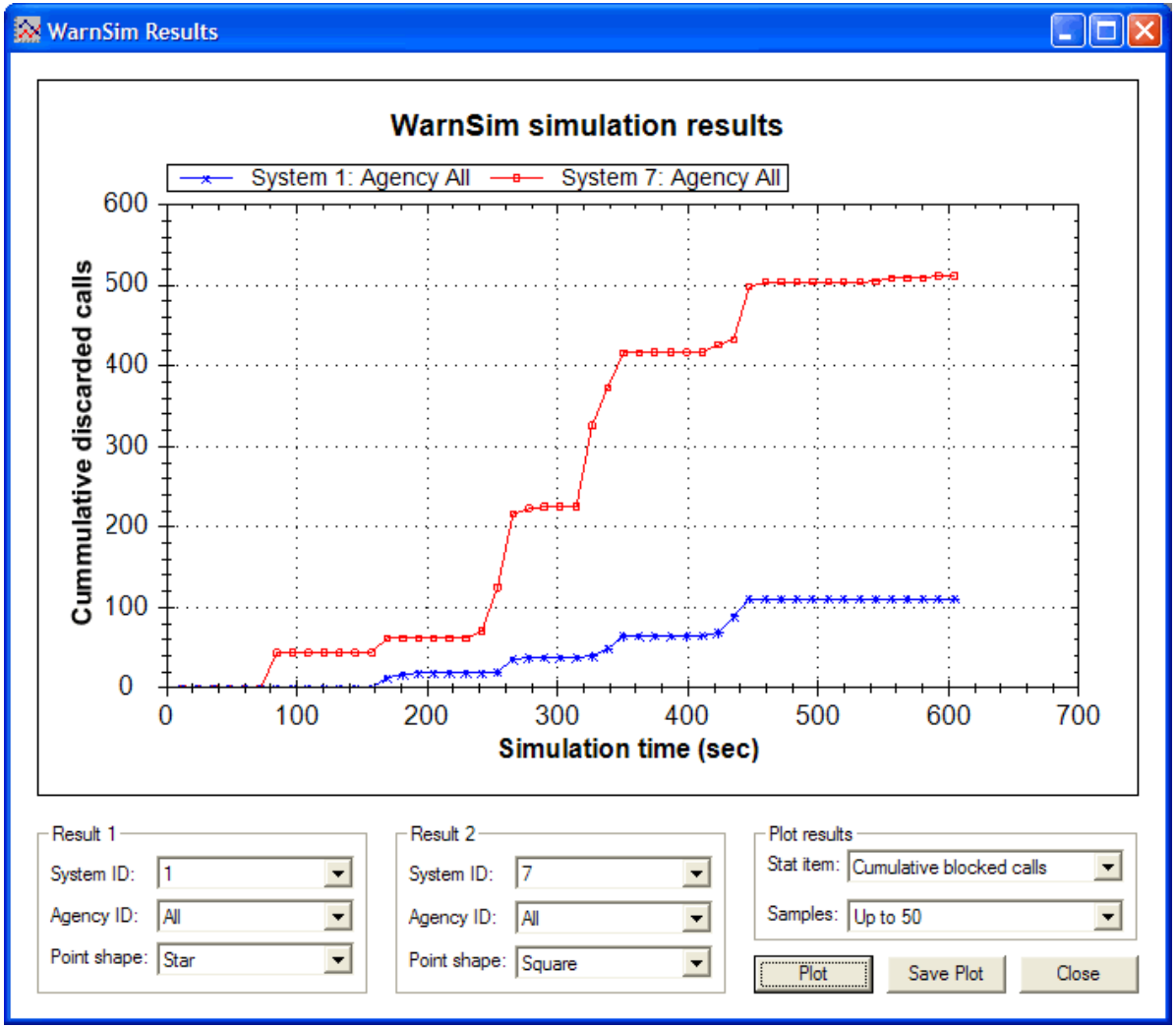
WarnSim: module diagram



Traffic trace generator



WarnSim results



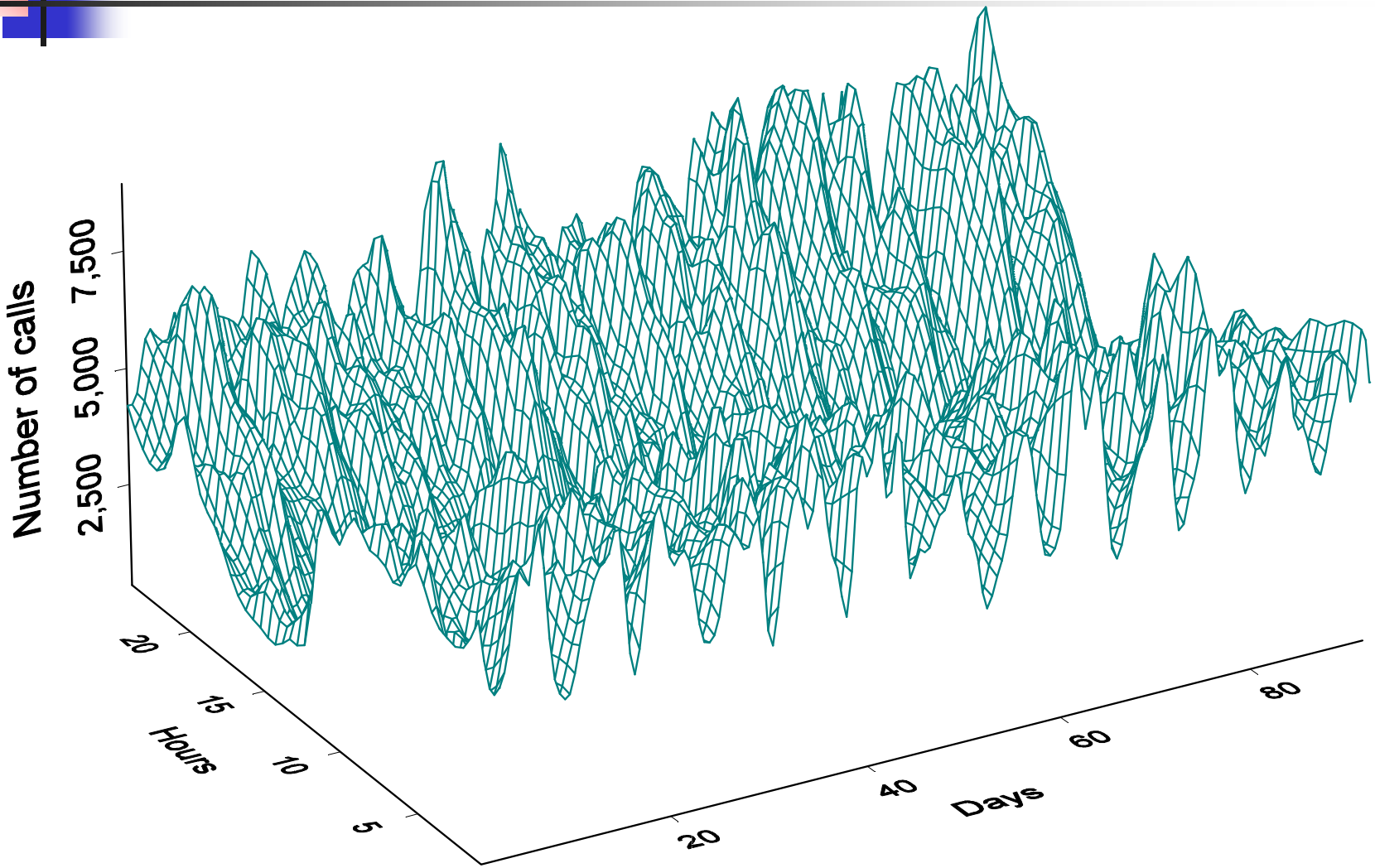
Traffic data

- 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:

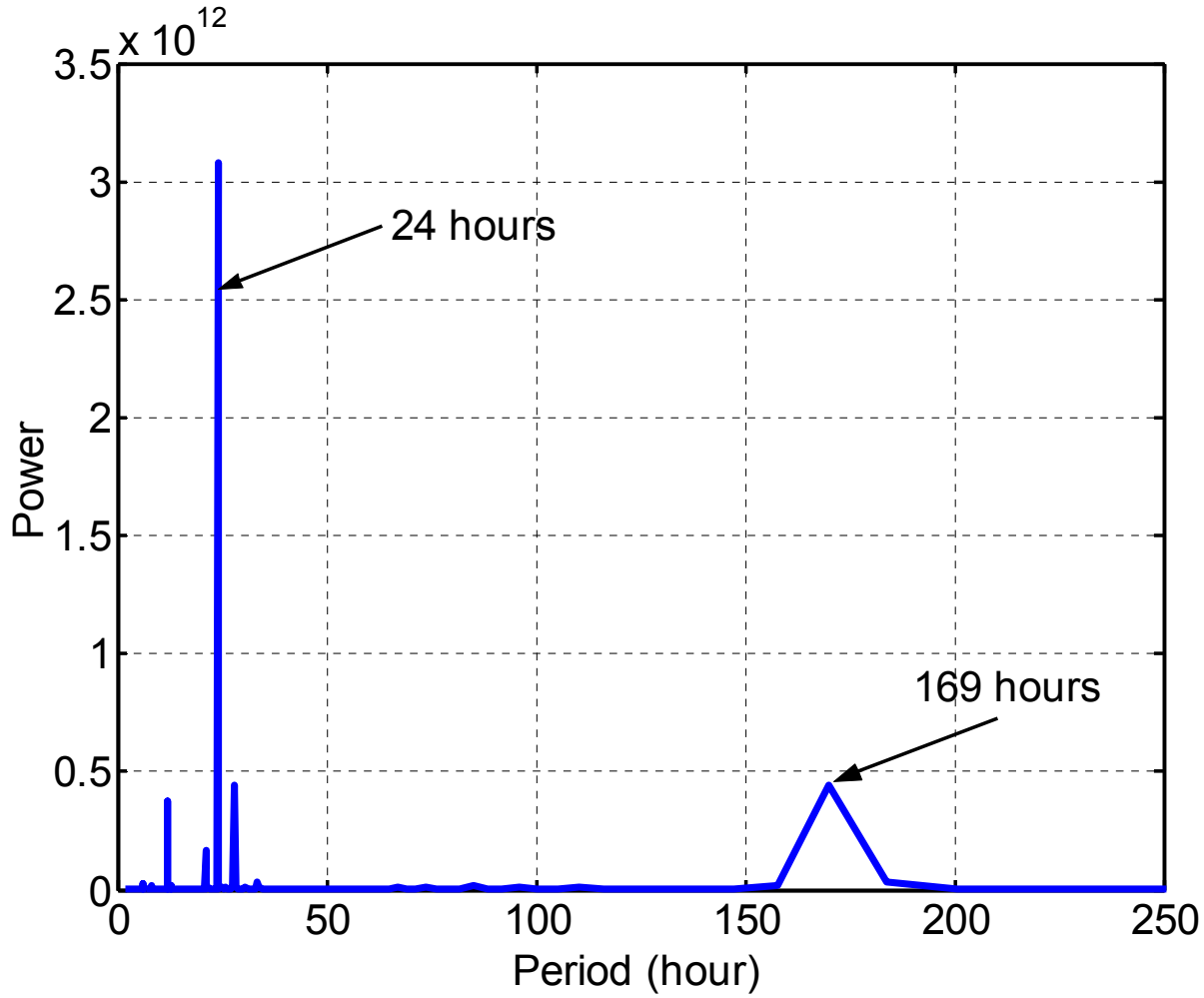
Call arrival time	Duration (ms)	Caller agency
2003-05-01 00:00:09.620	1990	5

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

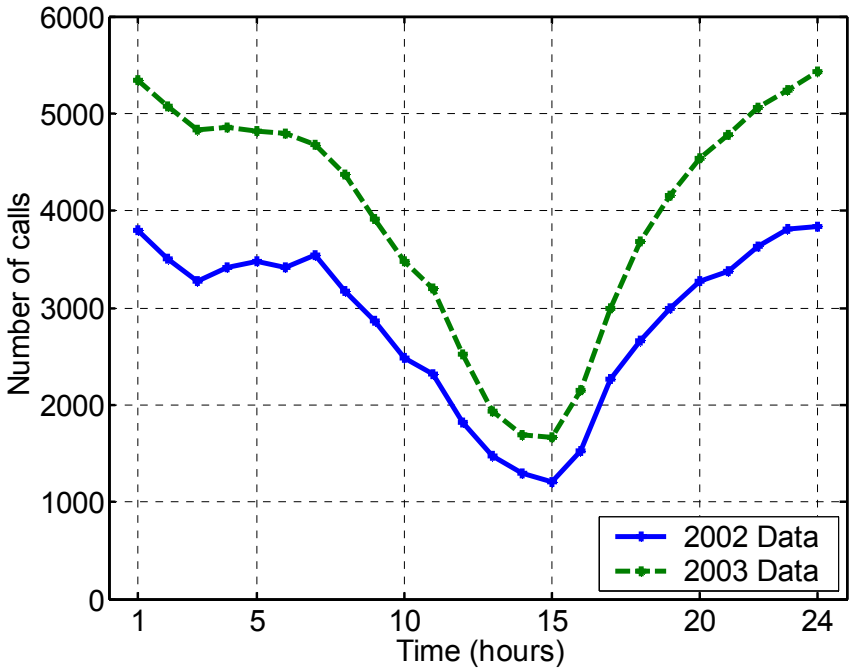
Hourly call arrival rate in 2003

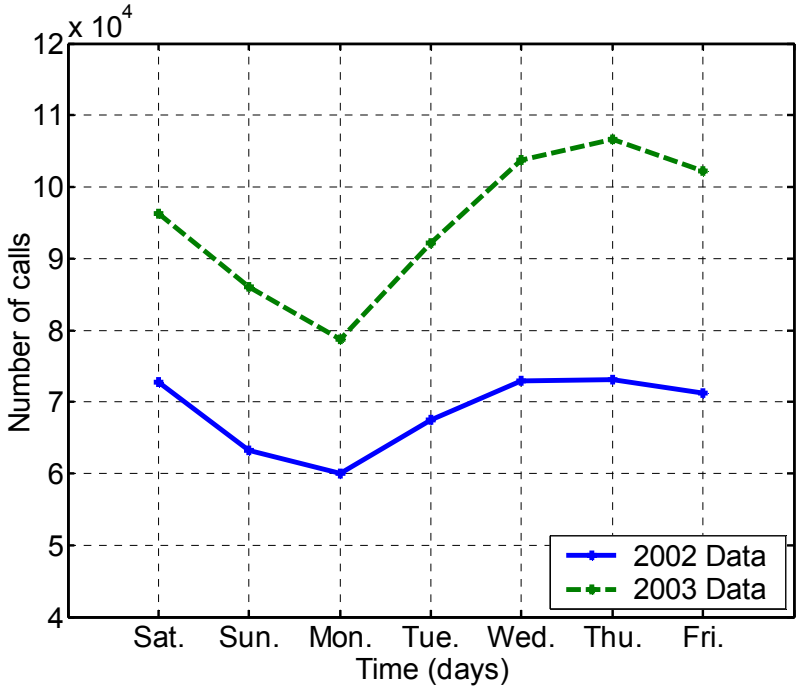


Hourly call arrival rate in 2003: power spectrum



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

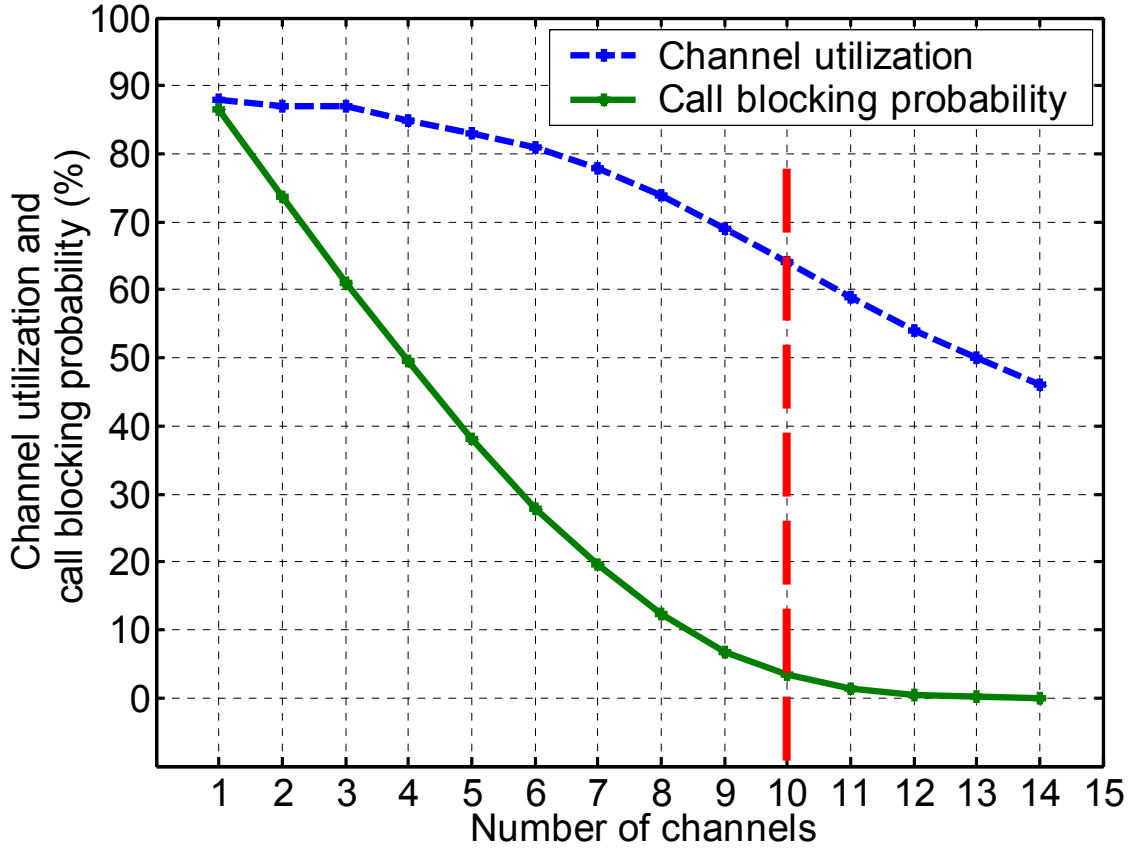
- Modeling of traffic on user agency level
- Extract 500 data samples (call holding time/call inter-arrival time) from traffic data table
- Select a candidate distribution (exponential, lognormal, or gamma) and use Maximum Likelihood Estimation to estimate its parameters
- Use Kolmogorov-Smirnov goodness-of-fit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

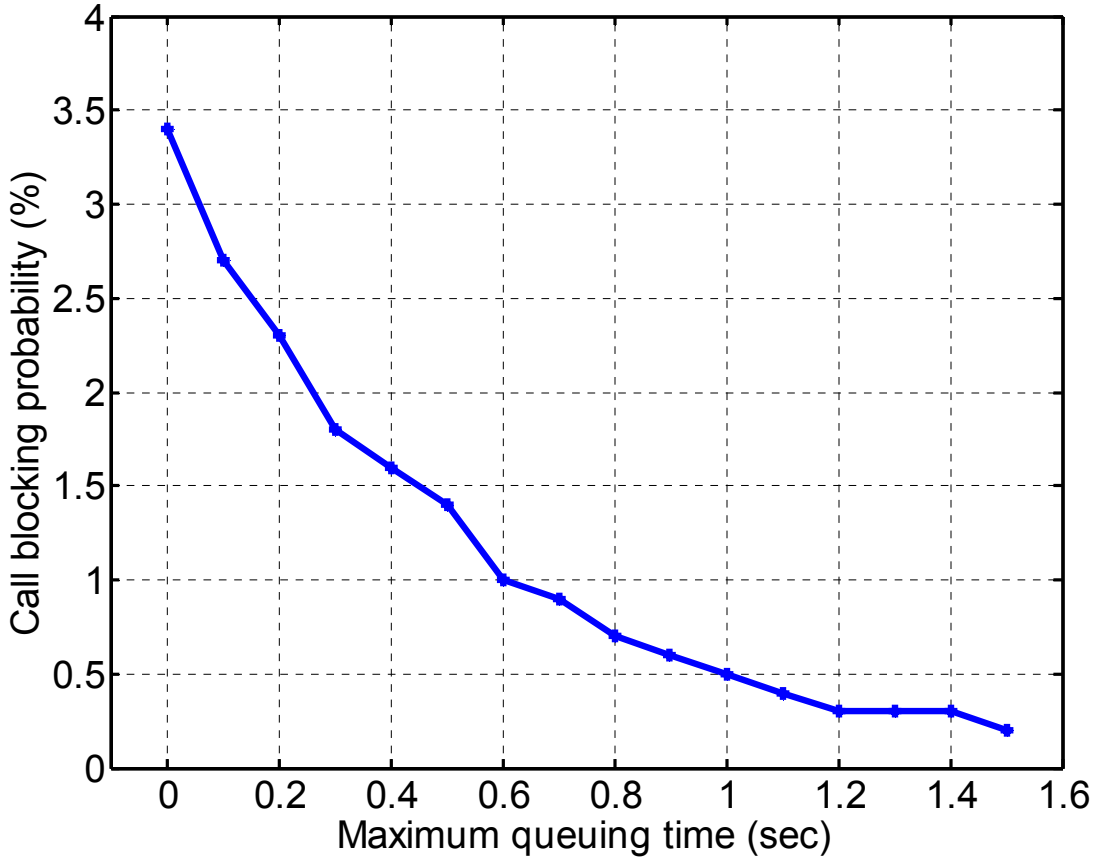
	Agency 2	Agency 5	Others
Call holding time	lognormal σ = 8.05 μ = 0.55	lognormal σ = 8.09 μ = 0.73	lognormal σ = 7.88 μ = 0.82
Call inter-arrival time	exponential β_1	exponential β_2	exponential β_3

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 σ = 8.05 μ = 0.55	lognormal σ = 8.09 μ = 0.73	lognormal σ = 7.88 μ = 0.82
Call inter-arrival time	exponential β = 1354	exponential β = 381	exponential β = 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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Thank you

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