

# QualNet: Overview and Examples

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Lecture № 12

# Outline

- 1 Introduction
- 2 Installation of QualNet 4.5.1
- 3 Simulation workflow
- 4 Example 1
- 5 Example 2
- 6 Large networks
- 7 Sample scenarios
- 8 Installation of QualNet 7.1

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- **Global Mobile Information System Simulator (GloMoSim)** – a network simulator
  - Project: 1997 – 2000
  - Sponsorship: Defense Advanced Research Projects Agency (DARPA)
  - Developer: University of California, Los Angeles (UCLA)
  - Language: PARSEC (a C-based parallel simulation language)
  - Project status: closed
- DARPA's requirements:
  - High speed
  - High scalability
  - Modeling and simulation of wireless and heterogeneous networks
- Software:
  - Open source
  - **Freeware**

# Introduction (cont'd)

- **QualNet** – the commercial spin-off of the GloMoSim simulator
  - Company: Scalable Network Technologies, Inc. (SCALABLE)
  - Founded: 1999
  - Founder: Dr. Rajive Bragodia (Parallel Computing Laboratory, UCLA)
  - <https://www.scalable-networks.com/>
- Application fields:
  - Research and development (R&D)
  - Planning and optimization
  - Education and training
- Software:
  - Open source
  - **Commercial**



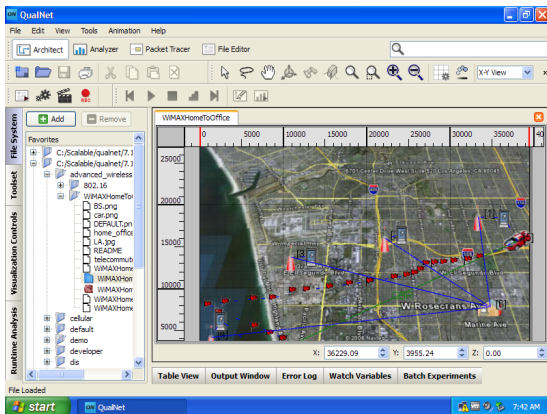
- Customers:
  - 1 **Service providers**
    - AT&T, France Telecom, NTT DoCoMo, ...
  - 2 **Enterprises**
    - Microsoft, Panasonic, TOSHIBA, TOYOTA, ...
  - 3 **Network equipment manufacturers**
    - Lucent Technologies, ...
  - 4 **Defense and homeland security**
    - NASA, US Air Force, US Army, US Navy, ...
  - 5 **Universities**
    - **SCALABLE EDU Program**

# Introduction (cont'd)

- Official site:
  - <https://www.scalable-networks.com/>
- Recent version:
  - **qualnet-9.2**, 2020
- Operating systems:
  - Windows
  - Linux

# Introduction (cont'd)

- QualNet key capabilities:
  - High scalability enables more sophisticated design and analysis
  - Faster-than-real-time simulation optimizes productivity
  - High-fidelity models deliver more accurate results





- **Graphical User Interface (GUI)**
  - Easy-to-use
- **Sophisticated analysis**
  - Integrated GUI-based debugging and analysis
- **High-fidelity modeling**
  - Various equipment and protocols, terrain and weather effects
- **Scalable simulation**
  - 32-bit and 64-bit fully parallel simulation kernel
  - Grid computing support for distributed simulation
- **Integrating live network and application behavior**
  - Commands that control various elements during scenario execution
  - Protocols and mechanisms that enable interaction with other systems

- Built for speed:
  - Takes full advantage of the multi-threading capabilities of multi-core, multi-processor, cluster and 64-bit processor systems
  - Supports simulation with 1000s of network nodes
- Example:
  - 'A cluster of 16 dual 2GHz Opteron systems connected by an Infiniband switch achieved real-time speed for 3,500 nodes'

# Outline

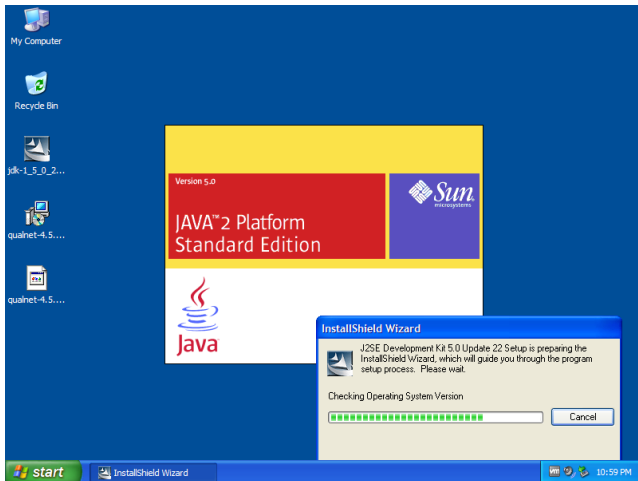
- 1 Introduction
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# Installation of QualNet 4.5.1

- System requirements:
  - Sun Java 2 SDK, Standard Edition (1.4.2 or higher)
  - C++ compiler (VC7 or higher)
  - Setting environment variables
- Installation order:
  - 1 Sun Java SDK
  - 2 QualNet
  - 3 License
- Free 30-day trial
  - qualnet-4\_5\_1-eval-YYYY.MM.DD.lic
  - 'YYYY.MM.DD' = delivery date

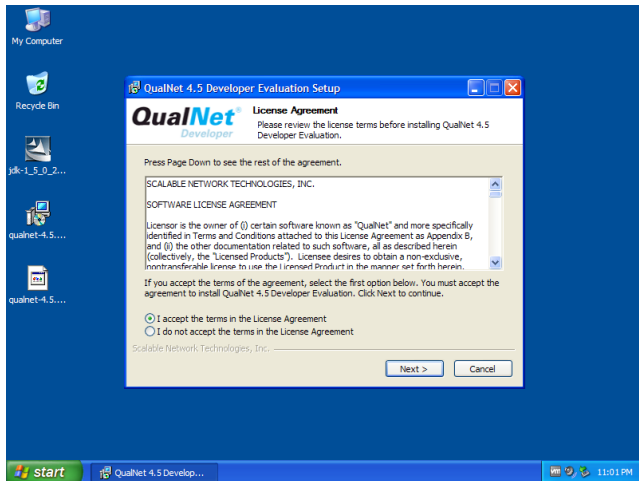
# Installation of QualNet 4.5.1 (cont'd)

- Install **J2SE Development Kit 5.0 Update 22**
  - `jdk-1_5_0_22-windows-i586-p.exe`



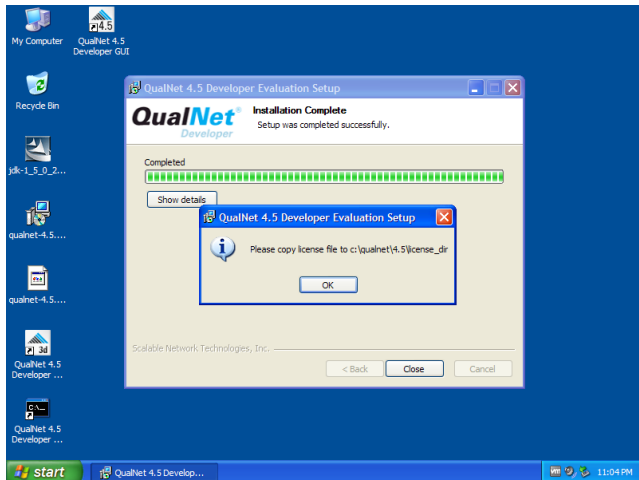
# Installation of QualNet 4.5.1 (cont'd)

- Install **QualNet 4.5.1**
  - qualnet-4\_5\_1-evaluation-installer.exe



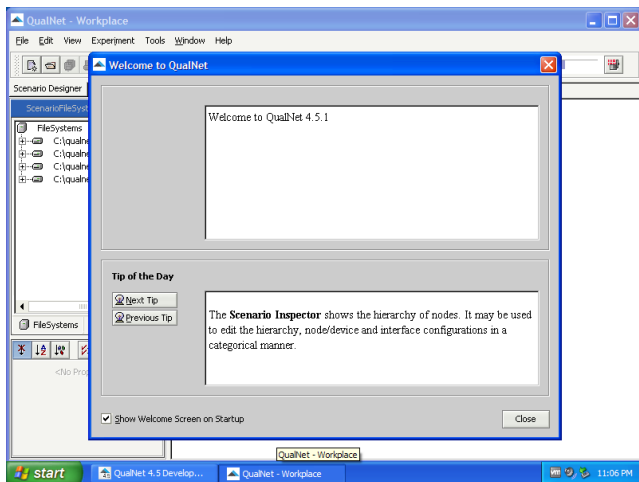
# Installation of QualNet 4.5.1 (cont'd)

- Copy license file
  - qualnet-4\_5\_1-eval-YYYY.MM.DD.lic



# Installation of QualNet 4.5.1 (cont'd)

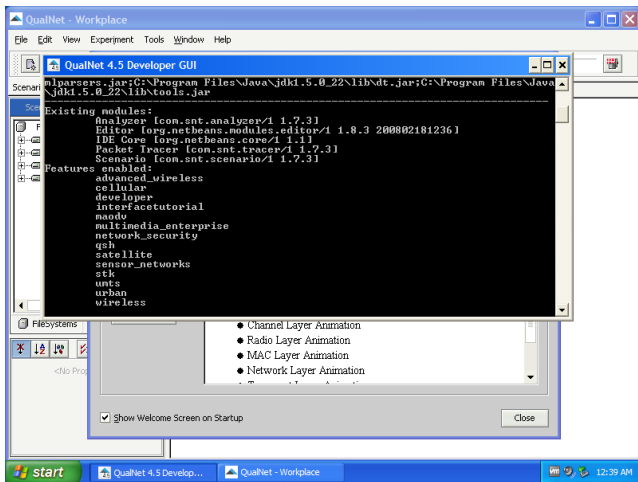
- Done!





# Installation of QualNet 4.5.1 (cont'd)

- Installed modules and features enabled



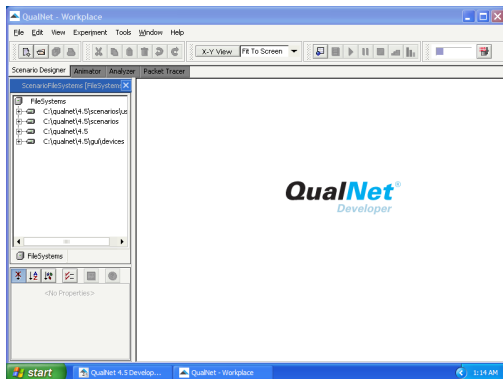
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- **QualNet simulation workflow** :
  - 1 Create a baseline scenario
    - Define the network topology
    - Create traffic
    - Choose statistics to be collected
    - Run the simulation
    - View the results
  - 2 Duplicate the scenario
    - Make changes
    - Re-run the simulation
    - Compare the obtained results
  - 3 Repeat №2 if needed

# Simulation Workflow (cont'd)

- QualNet 4.5 Developer GUI
  - **Scenario Designer** – model setup tool
  - **Animator** – visualization and analysis tool
  - **Analyzer** – statistical graphing tool
  - **Packet Tracer** – packet-level visualization tool

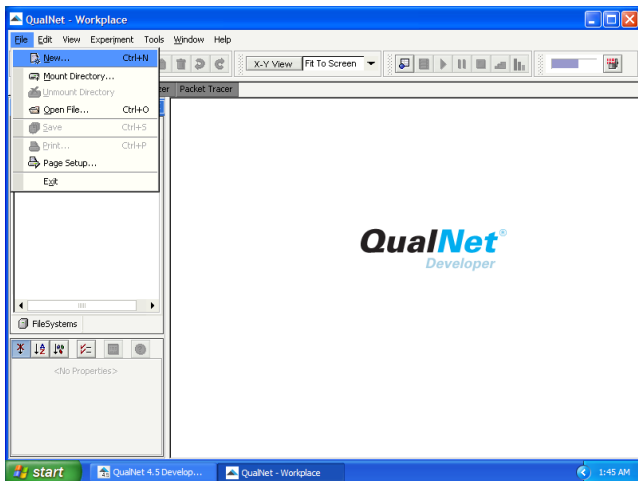


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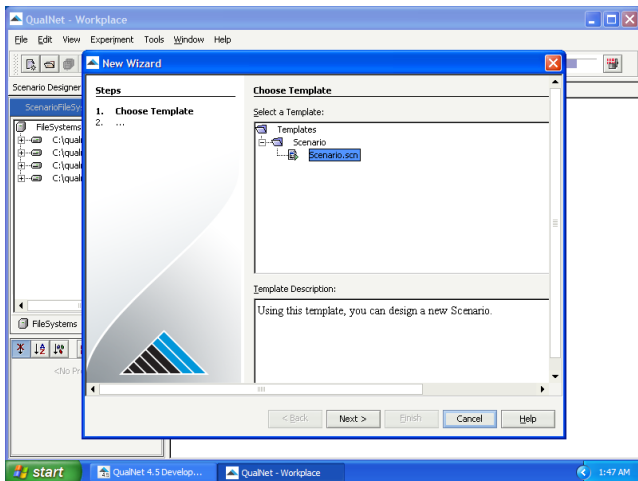
# Example 1

- Create a new scenario



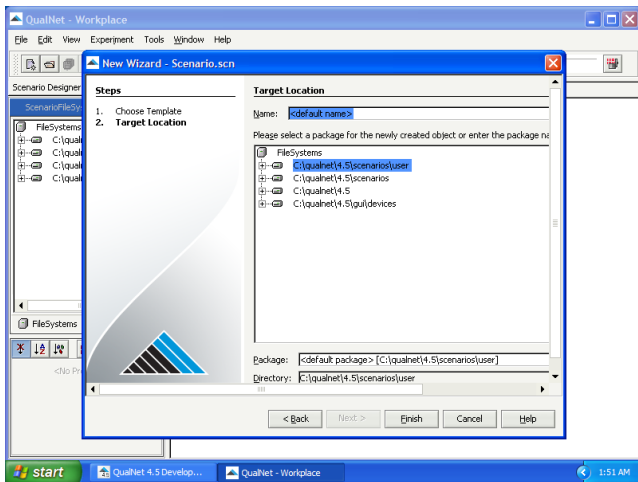
# Example 1 (cont'd)

- Create a new scenario



# Example 1 (cont'd)

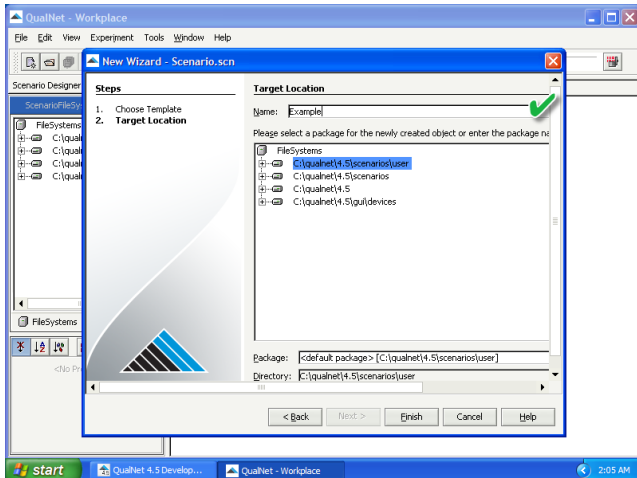
- Create a new scenario





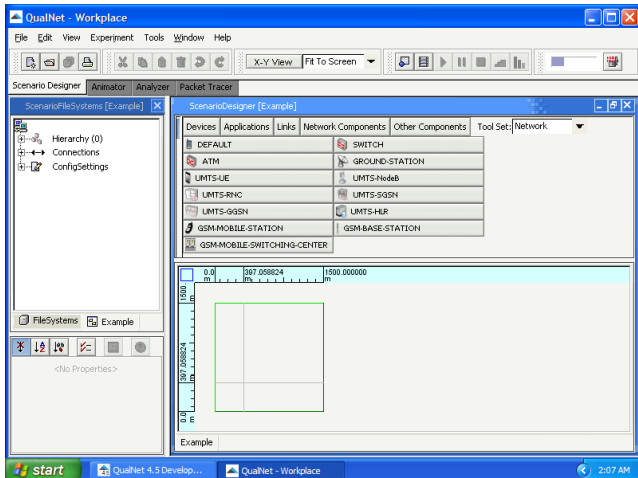
# Example 1 (cont'd)

- Save as 'Example'



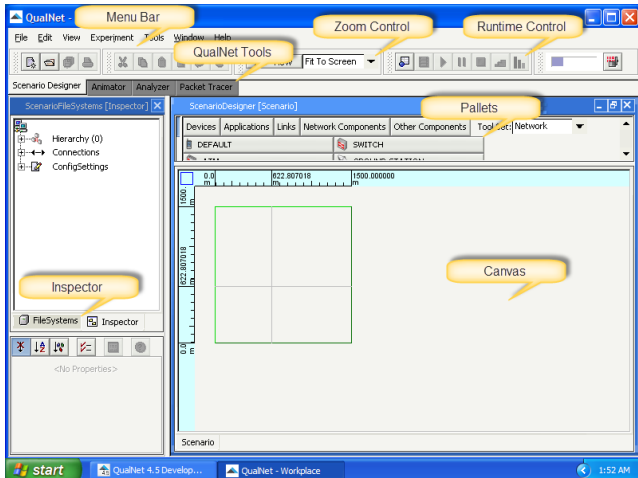
# Example 1 (cont'd)

- Scenario 'Example'



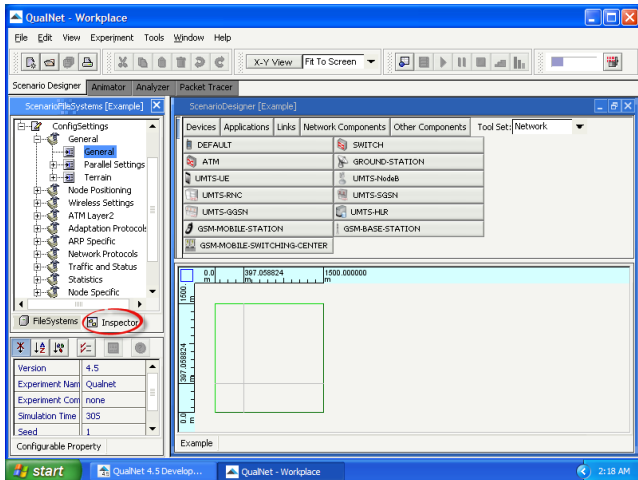
# Example 1 (cont'd)

- QualNet 4.5.1 workspace



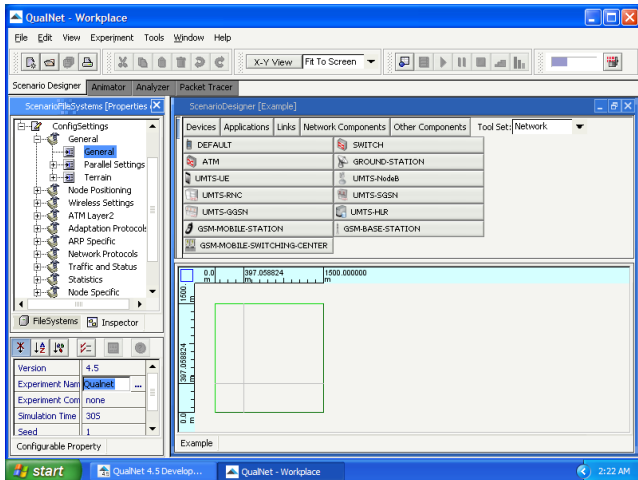
# Example 1 (cont'd)

- Save output as 'Example.date\_time.stat'



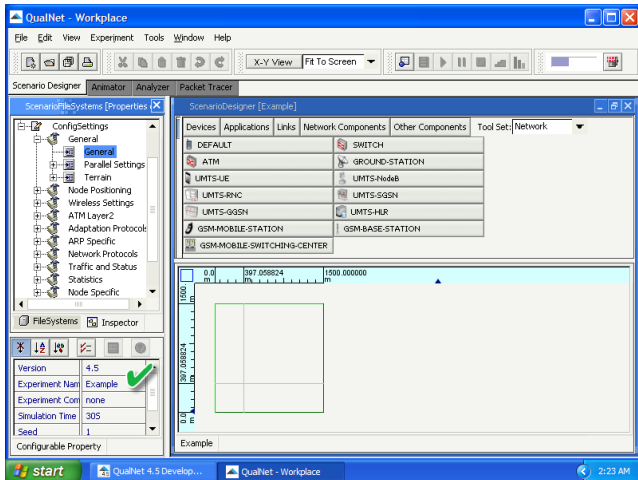
# Example 1 (cont'd)

- Save output as 'Example.date\_time.stat'



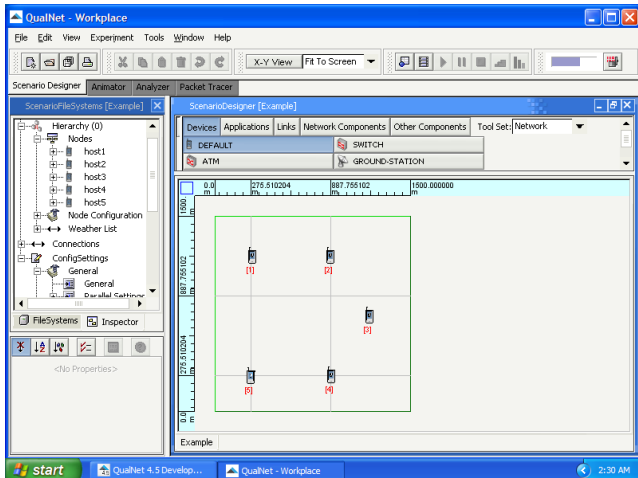
# Example 1 (cont'd)

- Save output as 'Example.date\_time.stat'



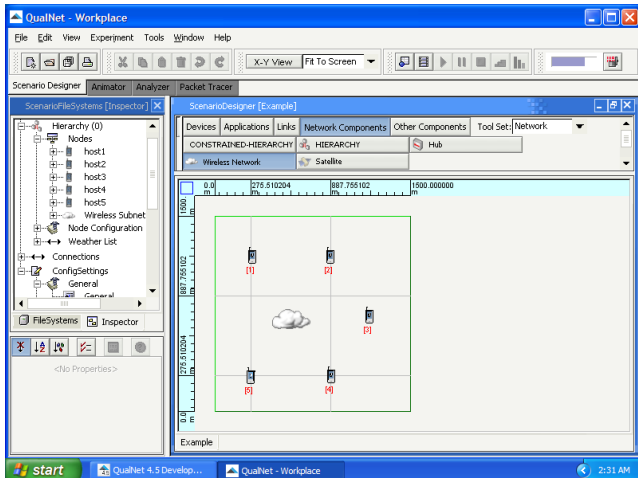
# Example 1 (cont'd)

- Define the topology of a wireless network



# Example 1 (cont'd)

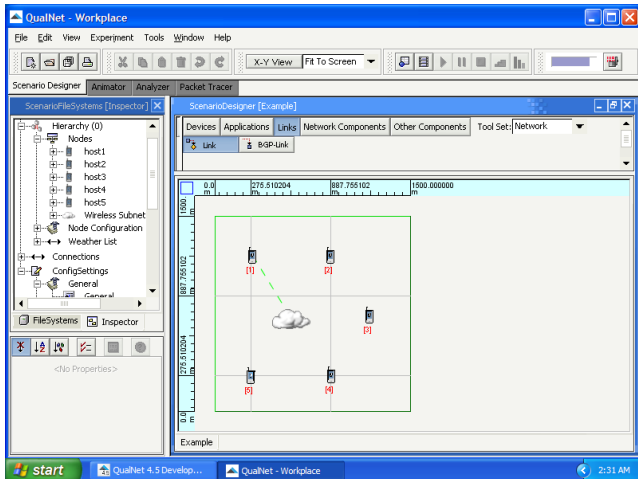
- Define the topology of a wireless network





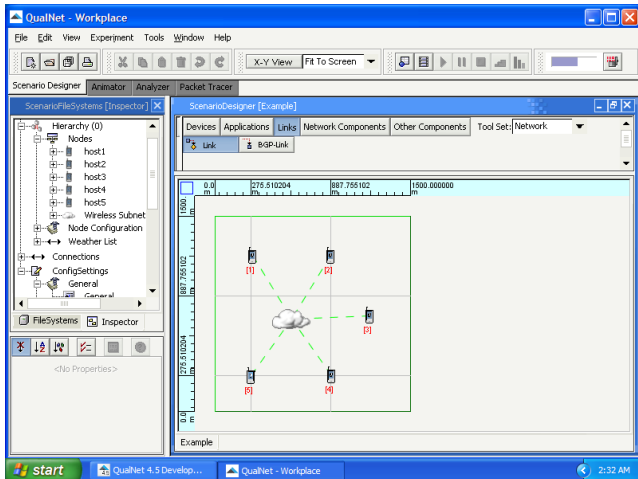
# Example 1 (cont'd)

- Define the topology of a wireless network



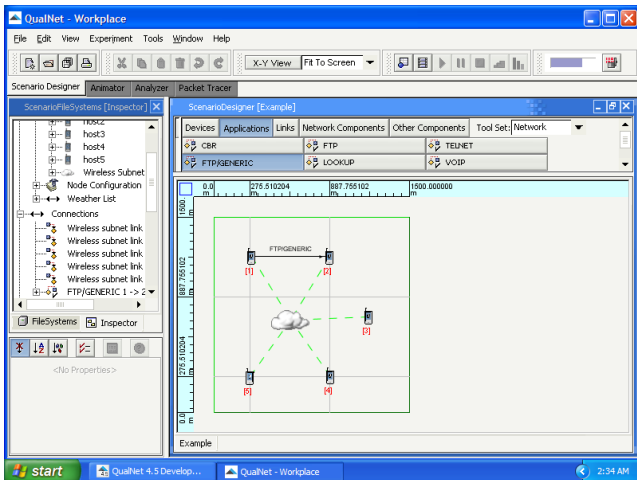
# Example 1 (cont'd)

- Define the topology of a wireless network



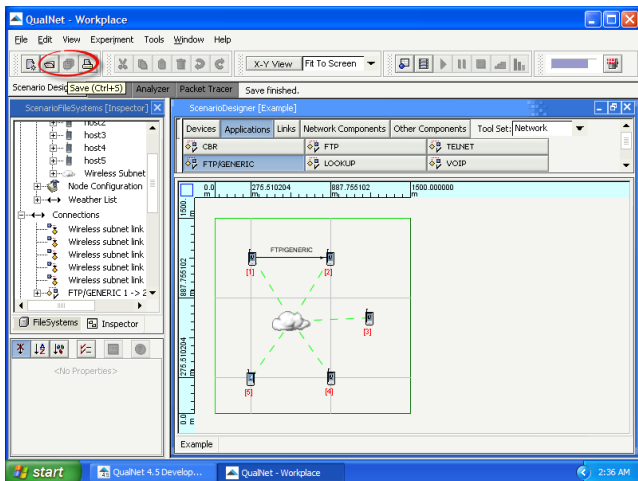
# Example 1 (cont'd)

- Create traffic



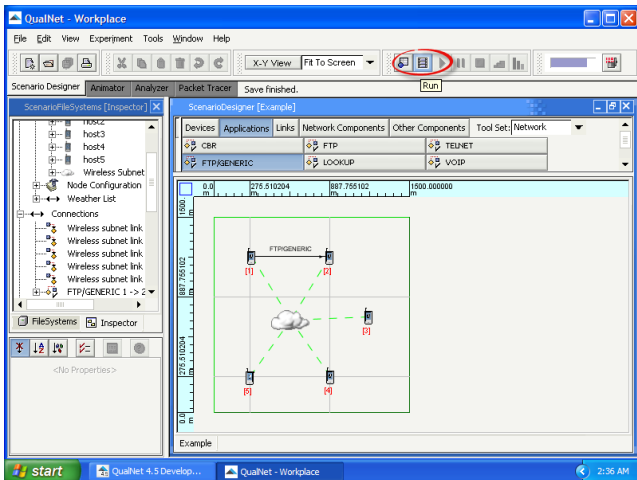
# Example 1 (cont'd)

- Save the scenario



# Example 1 (cont'd)

- Run the simulation



# Example 1 (cont'd)

- View the network animation

The screenshot displays the QualNet - Workplace application window. The main interface is divided into several panes:

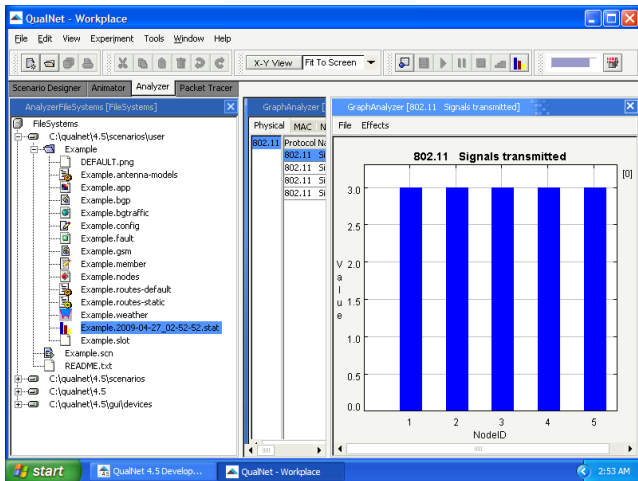
- Scenario Designer:** Shows the current scenario named "Example\_run\_1[Interactive]".
- Animator Window:** Displays a 2D network topology with five mobile nodes (labeled [1] through [5]) and a central access point. Nodes [1], [2], [3], and [4] are connected to the access point via dashed green lines. A coordinate grid is overlaid on the scene, with axes ranging from 0.0 to 1500.0 meters.
- Simulation Controls:** Located on the right side, it includes:
  - Simulation Time: 00:08:55ms:347us
  - Real Time: 00h:00m:00s
  - Speed and Progress sliders.
  - Animation Filters: Layers (Node Mobility Animation, Node Link Animation, Broadcast Packet Animation).
- Output Window:** Shows simulation logs with the following data:

```
Current Sim Time[s] = 0.469980903 Real Time[s] = 109 Completed 1%
Current Sim Time[s] = 0.657044662 Real Time[s] = 109 Completed 2%
```

The Windows taskbar at the bottom shows the Start button, the QualNet 4.5 Development environment, and the current time as 2:48 AM.

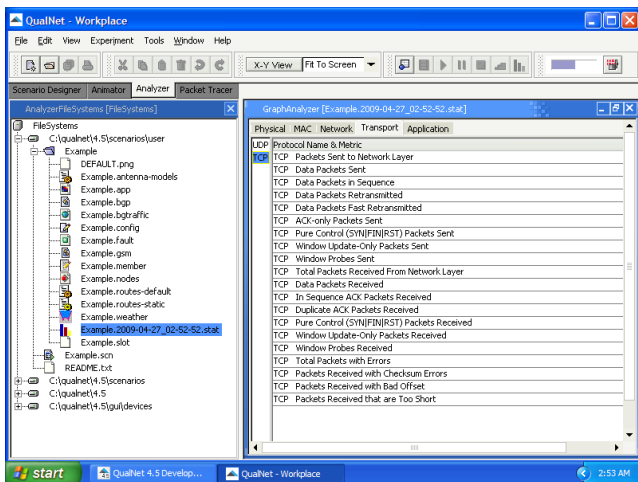
# Example 1 (cont'd)

- View the results



# Example 1 (cont'd)

- Available TCP statistics



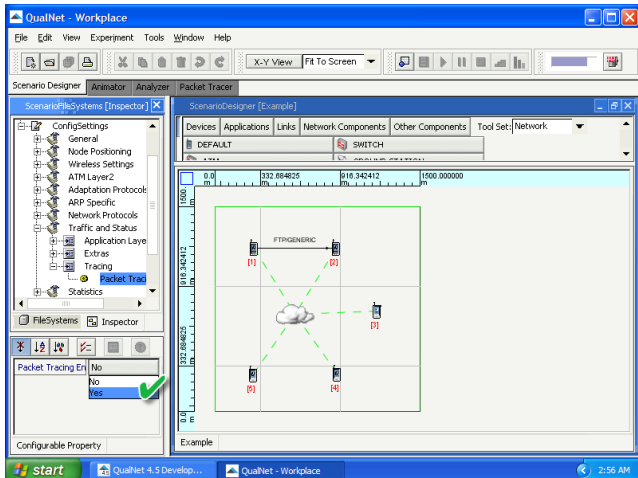
The screenshot shows the QualNet software interface. The main window is titled "QualNet - Workplace" and contains several panes. On the left is the "Scenario Designer" pane showing a file system tree with "Example, 2009-04-27\_02-52-52.stat" selected. The right pane is "GraphAnalyzer [Example, 2009-04-27\_02-52-52.stat]" and displays a table of TCP statistics under the "Transport" tab.

Protocol Name & Metric
TCP Packets Sent to Network Layer
TCP Data Packets Sent
TCP Data Packets in Sequence
TCP Data Packets Retransmitted
TCP Data Packets Fast Retransmitted
TCP ACK-only Packets Sent
TCP Pure Control (SYN FIN RST) Packets Sent
TCP Window Update-Only Packets Sent
TCP Window Probes Sent
TCP Total Packets Received From Network Layer
TCP Data Packets Received
TCP In Sequence ACK Packets Received
TCP Duplicate ACK Packets Received
TCP Pure Control (SYN FIN RST) Packets Received
TCP Window Update-Only Packets Received
TCP Window Probes Received
TCP Total Packets with Errors
TCP Packets Received with Checksum Errors
TCP Packets Received with Bad Offset
TCP Packets Received that are Too Short



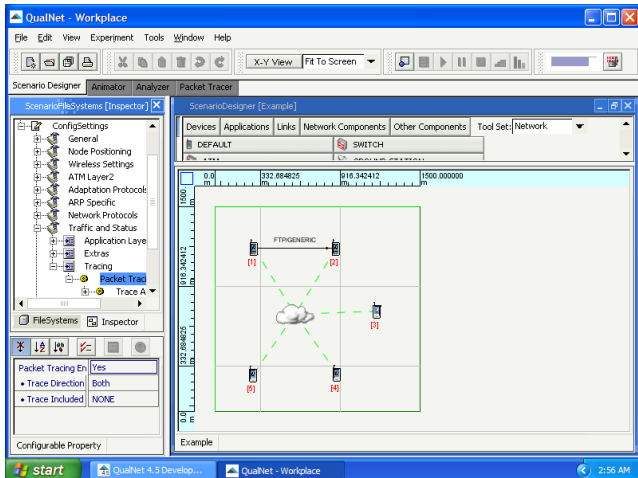
# Example 1 (cont'd)

- Capture packets



# Example 1 (cont'd)

- Capture packets



# Example 1 (cont'd)

- Transmitted packets

The screenshot displays the QualNet software interface. The 'Packet Tracer' window is active, showing a table of transmitted packets. The table has columns for S... (Source), T... (Destination), CheckTracing..., Tracing..., Sim. Time, Originati..., Messag..., and Action. The packets are numbered 1 through 20, showing various protocols like UDP and IPv4, and actions like SEND, ENQUEUE, and DEQUEUE.

S...	T...	CheckTracing...	Tracing...	Sim. Time	Originati...	Messag...	Originati...	Action
1	1	<input type="checkbox"/>	<input type="checkbox"/>	0.0	BELLMA...	0	BELLMA...	SEND
2	2	<input type="checkbox"/>	<input type="checkbox"/>	0.0	BELLMA...	0	BELLMA...	SEND
3	3	<input type="checkbox"/>	<input type="checkbox"/>	0.0	BELLMA...	0	BELLMA...	SEND
4	4	<input type="checkbox"/>	<input type="checkbox"/>	0.0	BELLMA...	0	BELLMA...	SEND
5	5	<input type="checkbox"/>	<input type="checkbox"/>	0.0	BELLMA...	0	BELLMA...	SEND
6	4	<input type="checkbox"/>	<input type="checkbox"/>	0.01044...	UDP	0	BELLMA...	SEND
7	4	<input type="checkbox"/>	<input type="checkbox"/>	0.01044...	IPv4	0	BELLMA...	SEND
8	4	<input type="checkbox"/>	<input type="checkbox"/>	0.01044...	IPv4	0	BELLMA...	ENQUEUE
9	4	<input type="checkbox"/>	<input type="checkbox"/>	0.01044...	IPv4	0	BELLMA...	DEQUEUE
10	5	<input type="checkbox"/>	<input type="checkbox"/>	0.04648...	UDP	0	BELLMA...	SEND
11	5	<input type="checkbox"/>	<input type="checkbox"/>	0.04648...	IPv4	0	BELLMA...	SEND
12	5	<input type="checkbox"/>	<input type="checkbox"/>	0.04648...	IPv4	0	BELLMA...	ENQUEUE
13	5	<input type="checkbox"/>	<input type="checkbox"/>	0.04648...	IPv4	0	BELLMA...	DEQUEUE
14	2	<input type="checkbox"/>	<input type="checkbox"/>	0.05370...	UDP	0	BELLMA...	SEND
15	2	<input type="checkbox"/>	<input type="checkbox"/>	0.05370...	IPv4	0	BELLMA...	SEND
16	2	<input type="checkbox"/>	<input type="checkbox"/>	0.05370...	IPv4	0	BELLMA...	ENQUEUE
17	2	<input type="checkbox"/>	<input type="checkbox"/>	0.05370...	IPv4	0	BELLMA...	DEQUEUE
18	3	<input type="checkbox"/>	<input type="checkbox"/>	0.11252...	UDP	0	BELLMA...	SEND
19	3	<input type="checkbox"/>	<input type="checkbox"/>	0.11252...	IPv4	0	BELLMA...	SEND
20	3	<input type="checkbox"/>	<input type="checkbox"/>	0.11252...	IPv4	0	BELLMA...	ENQUEUE

# Example 1 (cont'd)

- Transmitted packets

The screenshot displays the QualNet - Workplace interface. On the left, the 'File System [Explorer]' window shows the configuration for a TCP protocol, including source and destination ports, sequence and acknowledgment numbers, flags (SYN=1), and window size. The main window, 'Packet Tracer [Example.2009-04-27\_02-58-51]', shows a table of transmitted packets. The table has columns for 'S...', 'T...', 'CheckTracing...', 'Tracing...', 'Sim. Time', 'Originati...', 'Messag...', 'Originati...', and 'Action'. The table contains 15 rows of data, with the 29th row highlighted in blue.

S...	T...	CheckTracing...	Tracing...	Sim. Time	Originati...	Messag...	Originati...	Action
15		<input type="checkbox"/>	<input type="checkbox"/>	0.05370...	2	0	BELLMA...	SEND
16		<input type="checkbox"/>	<input type="checkbox"/>	0.05370...	2	0	BELLMA...	ENQUEUE
17		<input type="checkbox"/>	<input type="checkbox"/>	0.05370...	2	0	BELLMA...	DEQUEUE
18		<input type="checkbox"/>	<input type="checkbox"/>	0.11252...	3	0	BELLMA...	SEND
19		<input type="checkbox"/>	<input type="checkbox"/>	0.11252...	3	0	BELLMA...	SEND
20		<input type="checkbox"/>	<input type="checkbox"/>	0.11252...	3	0	BELLMA...	ENQUEUE
21		<input type="checkbox"/>	<input type="checkbox"/>	0.11252...	3	0	BELLMA...	DEQUEUE
22		<input type="checkbox"/>	<input type="checkbox"/>	0.14966...	1	0	BELLMA...	SEND
23		<input type="checkbox"/>	<input type="checkbox"/>	0.14966...	1	0	BELLMA...	SEND
24		<input type="checkbox"/>	<input type="checkbox"/>	0.14966...	1	0	BELLMA...	ENQUEUE
25		<input type="checkbox"/>	<input type="checkbox"/>	0.14966...	1	0	BELLMA...	DEQUEUE
26		<input type="checkbox"/>	<input type="checkbox"/>	1.0	1	1	TCP	SEND
27		<input type="checkbox"/>	<input type="checkbox"/>	1.0	1	1	TCP	SEND
28		<input type="checkbox"/>	<input type="checkbox"/>	1.0	1	1	TCP	DROP
29		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	6.65372...	1	2	TCP	SEND
30		<input type="checkbox"/>	<input type="checkbox"/>	6.65372...	1	2	TCP	SEND
31		<input type="checkbox"/>	<input type="checkbox"/>	6.65372...	1	2	TCP	DROP
32		<input type="checkbox"/>	<input type="checkbox"/>	10.0283...	5	1	BELLMA...	SEND
33		<input type="checkbox"/>	<input type="checkbox"/>	10.0474...	4	1	BELLMA...	SEND
34		<input type="checkbox"/>	<input type="checkbox"/>	10.0661...	3	1	BELLMA...	SEND

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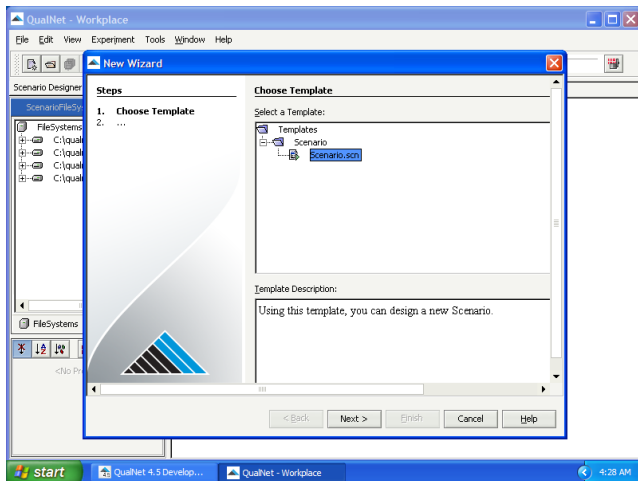
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## Example 2

- **Topology:** point-to-point
- **Nodes:** 2
- **Data rate:** 2 Mbps
- **Propagation time:** 1 ms
- **Application:** Constant Bit Rate (CBR)
- **Sender:** node №1
- **Receiver:** node №2
- **Simulation time:** 10 s
- **Traffic:** packets = 10, size = 512 B, inter-departure time = 1 s

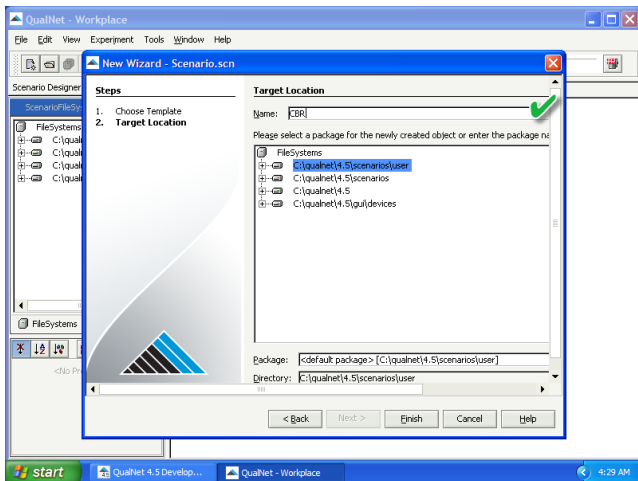
# Example 2 (cont'd)

- Create a new scenario



## Example 2 (cont'd)

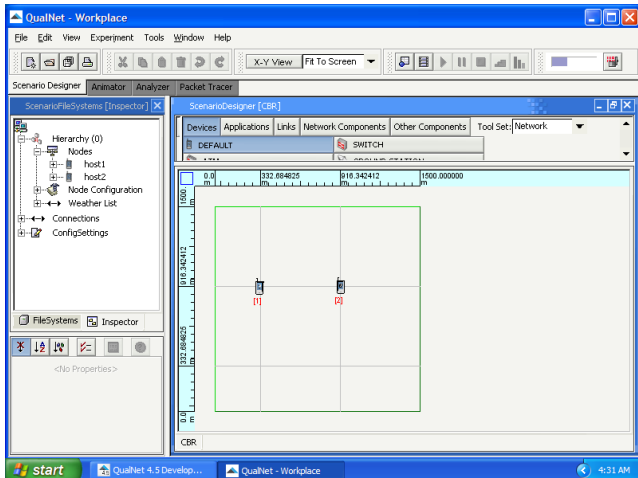
- Save as 'CBR'





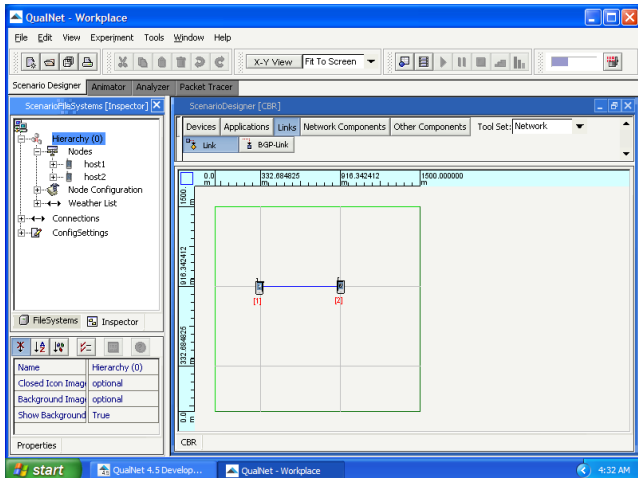
## Example 2 (cont'd)

- Create the point-to-point topology



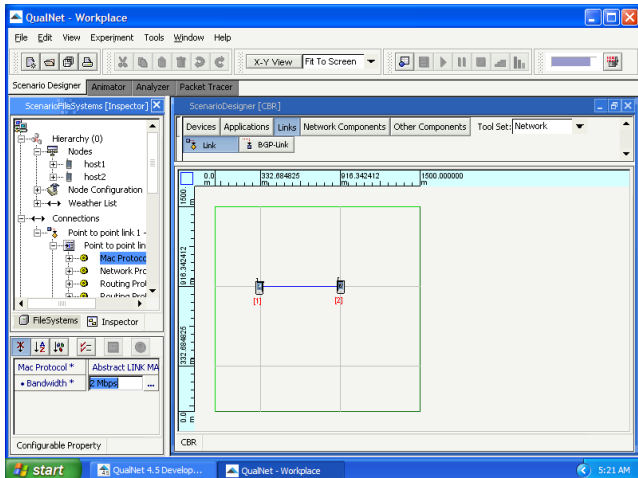
## Example 2 (cont'd)

- Create the point-to-point topology



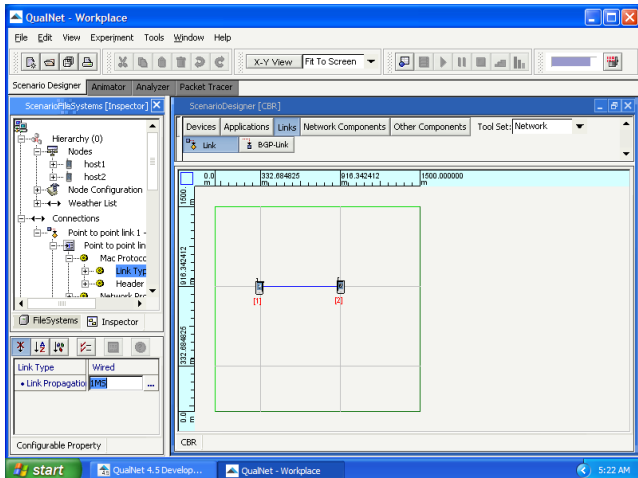
## Example 2 (cont'd)

- Set the bandwidth of the point-to-point link



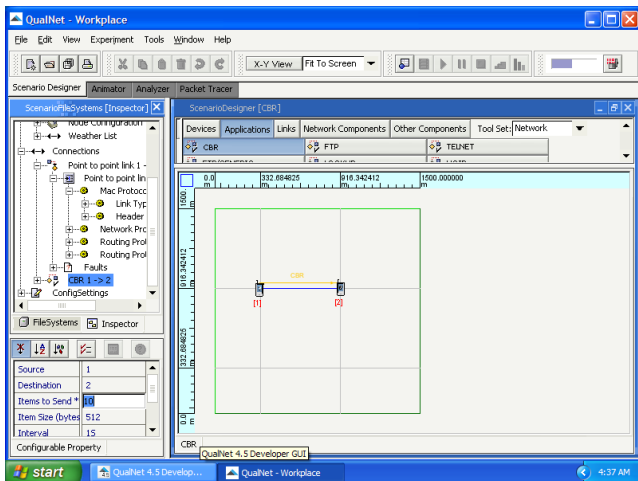
## Example 2 (cont'd)

- Set the link propagation time



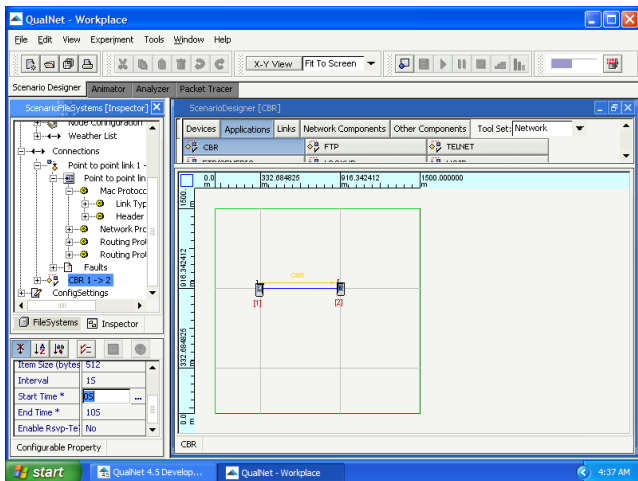
# Example 2 (cont'd)

- Create traffic



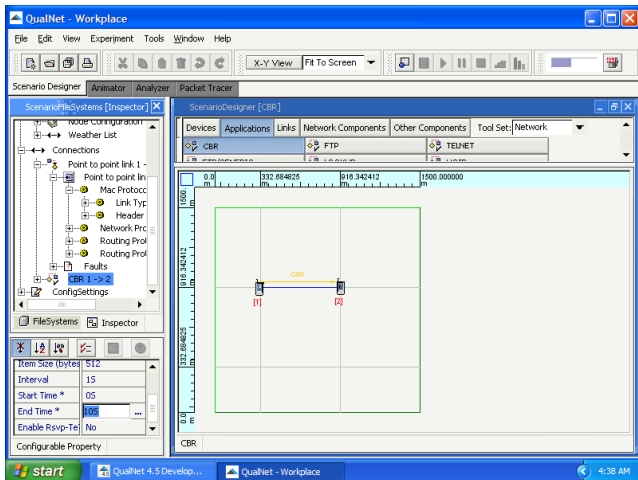
## Example 2 (cont'd)

- Set the start time



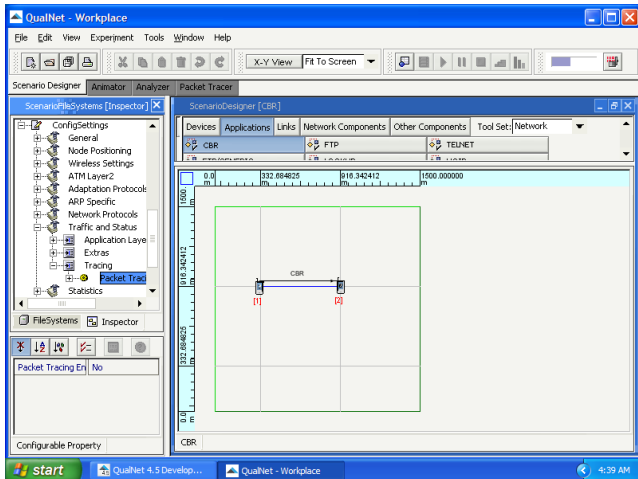
## Example 2 (cont'd)

- Set the end time



# Example 2 (cont'd)

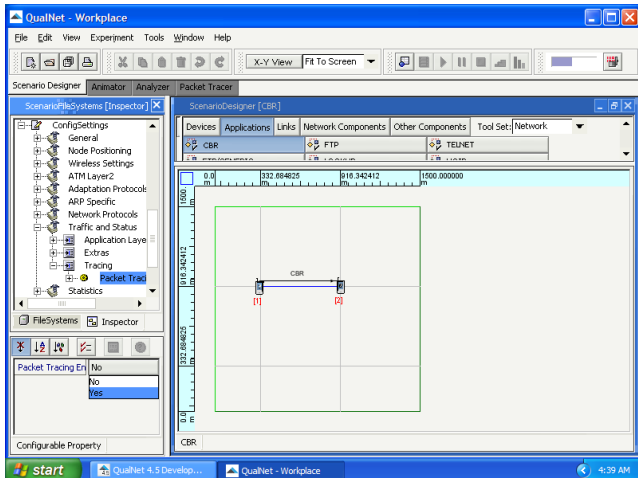
- Capture packets





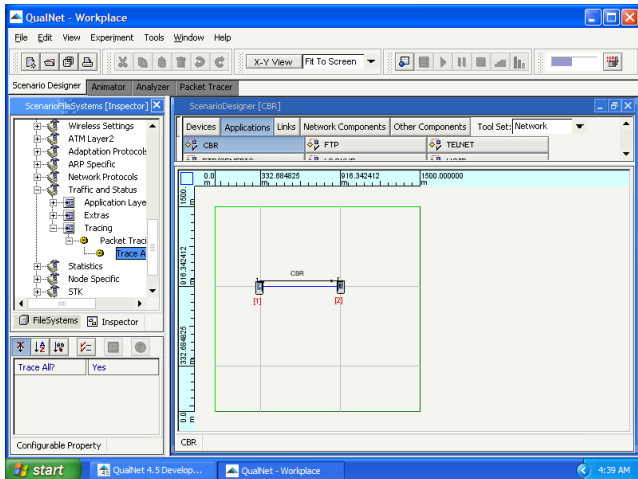
# Example 2 (cont'd)

- Capture packets



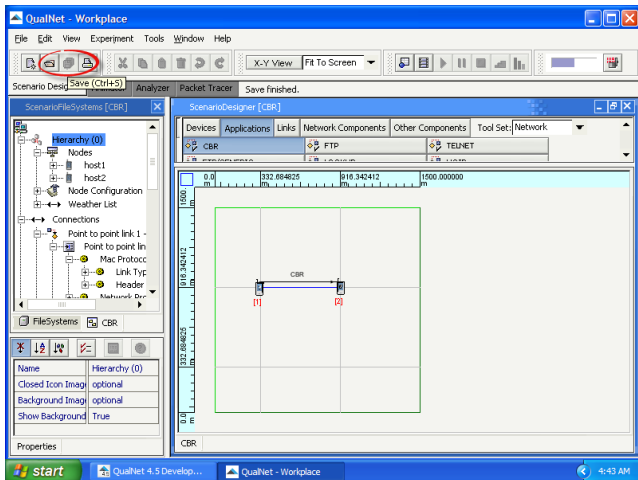
# Example 2 (cont'd)

- Capture packets



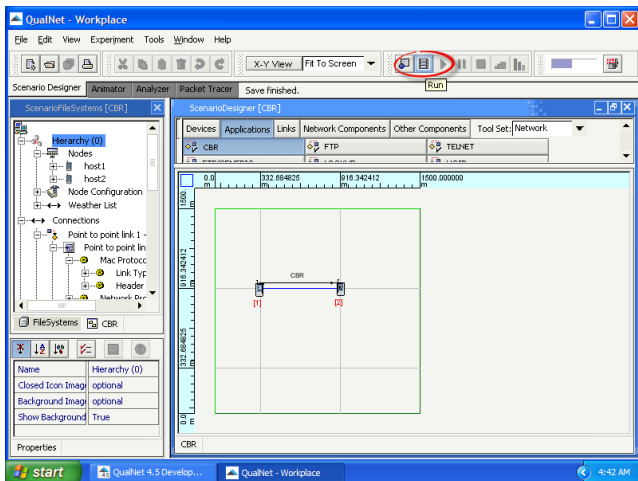
# Example 2 (cont'd)

- Save the scenario



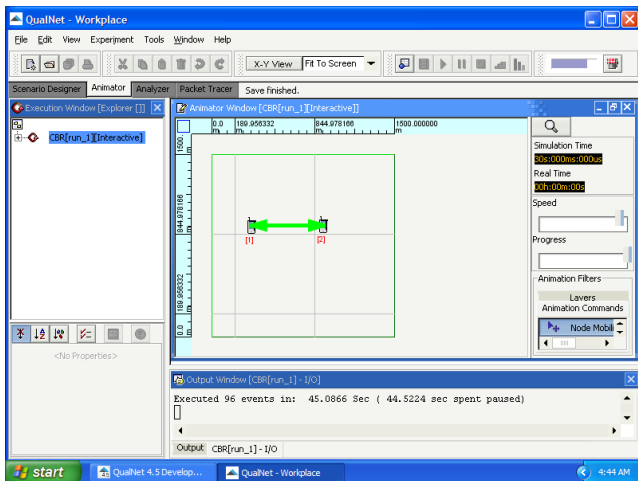
## Example 2 (cont'd)

- Run the simulation



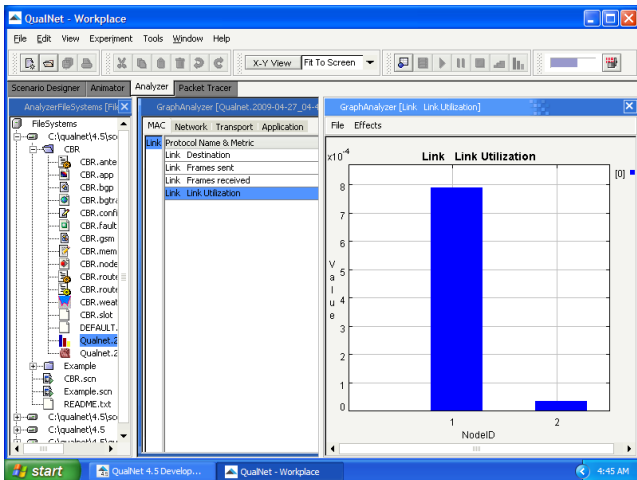
## Example 2 (cont'd)

- View the network animation



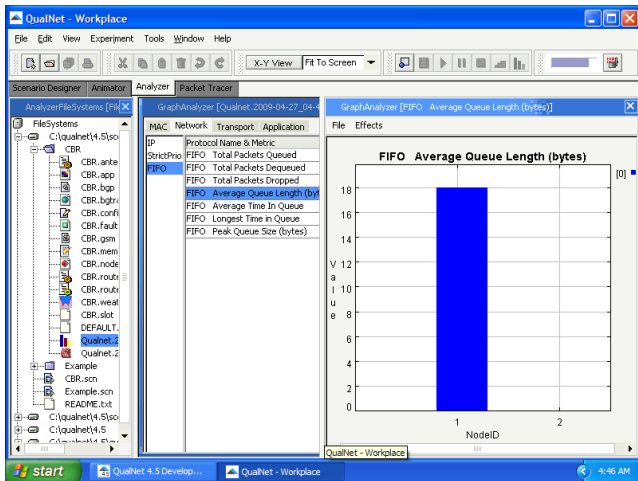
# Example 2 (cont'd)

- View the results



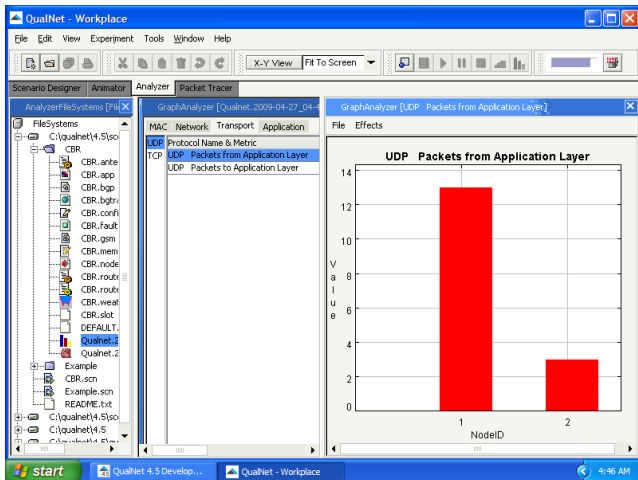
# Example 2 (cont'd)

- View the results



# Example 2 (cont'd)

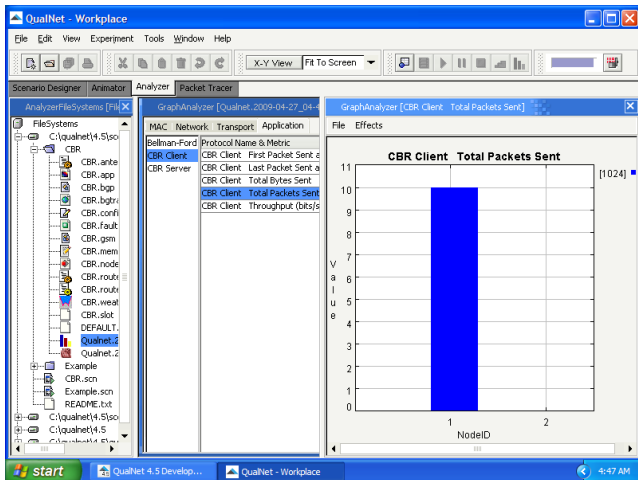
- View the results





# Example 2 (cont'd)

- View the results



# Example 2 (cont'd)

- Transmitted packets

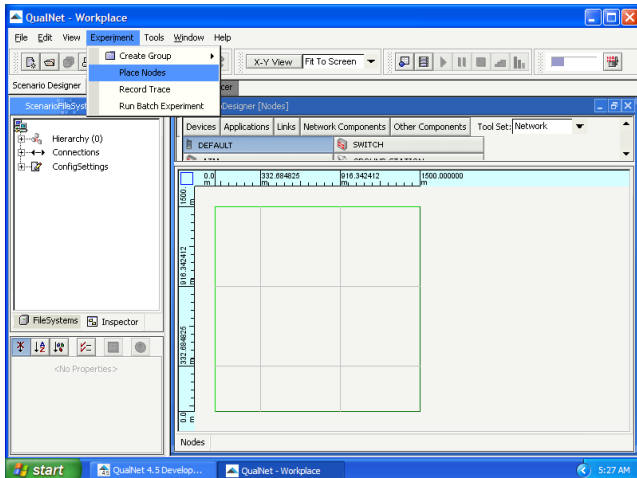
The screenshot shows the QualNet - Workplace interface with the Packet Tracer window active. The Packet Tracer window displays a list of transmitted packets with the following columns: Serial, Type, Check, Tracing Node, Tracing Pr..., Sim. Time, Originating..., Message S..., Originating..., and Action.

Serial	Type	Check	Tracing Node	Tracing Pr...	Sim. Time	Originating...	Message S...	Originating...	Action
1	CBR		1	CBR	0.0	1	0	CBR	SEND
2	UDP		1	UDP	0.0	1	0	CBR	SEND
3	IPv4		1	IPv4	0.0	1	0	CBR	SEND
4	IPv4		1	IPv4	0.0	1	0	CBR	ENQUEUE
5	IPv4		1	IPv4	0.0	1	0	CBR	DEQUEUE
6	BELLMANF...		1	BELLMANF...	0.0	1	0	BELLMANF...	SEND
7	BELLMANF...		2	BELLMANF...	0.0	2	0	BELLMANF...	SEND
8	IPv4		2	IPv4	0.003272	1	0	CBR	RCV
9	UDP		2	UDP	0.003272	1	0	CBR	RCV
10	CBR		2	CBR	0.003273	1	0	CBR	RCV
11	UDP		2	UDP	0.053704...	2	0	BELLMANF...	SEND
12	IPv4		2	IPv4	0.053704...	2	0	BELLMANF...	SEND
13	IPv4		2	IPv4	0.053704...	2	0	BELLMANF...	ENQUEUE
14	IPv4		2	IPv4	0.053704...	2	0	BELLMANF...	DEQUEUE
15	IPv4		1	IPv4	0.055040...	2	0	BELLMANF...	RCV
16	UDP		1	UDP	0.055040...	2	0	BELLMANF...	RCV
17	BELLMANF...		1	BELLMANF...	0.055041...	2	0	BELLMANF...	RCV
18	UDP		1	UDP	0.149668...	1	1	BELLMANF...	SEND
19	IPv4		1	IPv4	0.149668...	1	1	BELLMANF...	SEND
20	IPv4		1	IPv4	0.149668...	1	1	BELLMANF...	ENQUEUE

# Outline

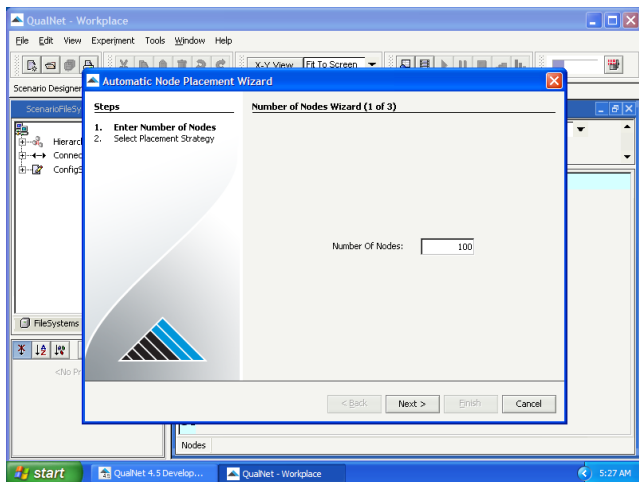
- 1 Introduction
- 2 Installation of QualNet 4.5.1
- 3 Simulation workflow
- 4 Example 1
- 5 Example 2
- 6 Large networks**
- 7 Sample scenarios
- 8 Installation of QualNet 7.1

- Automatic node placement



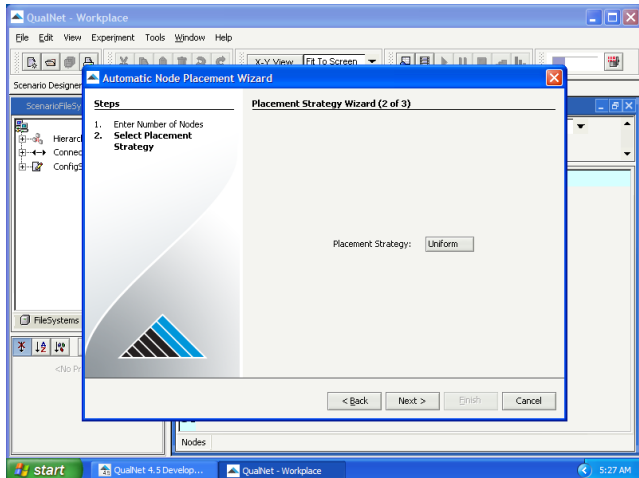
# Large Networks (cont'd)

- Number of nodes



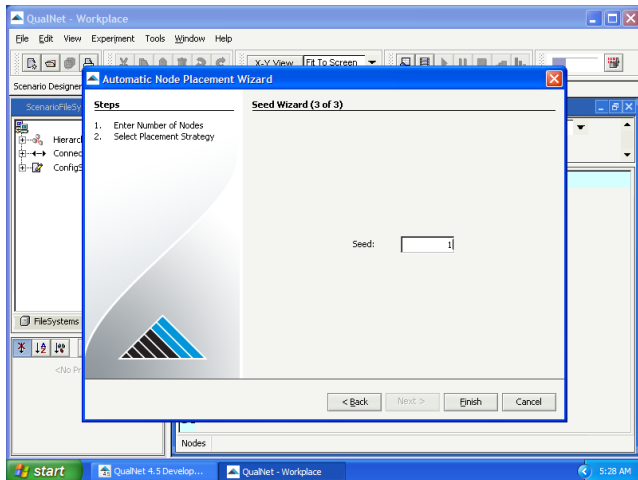
# Large Networks (cont'd)

- Placement strategy = uniform



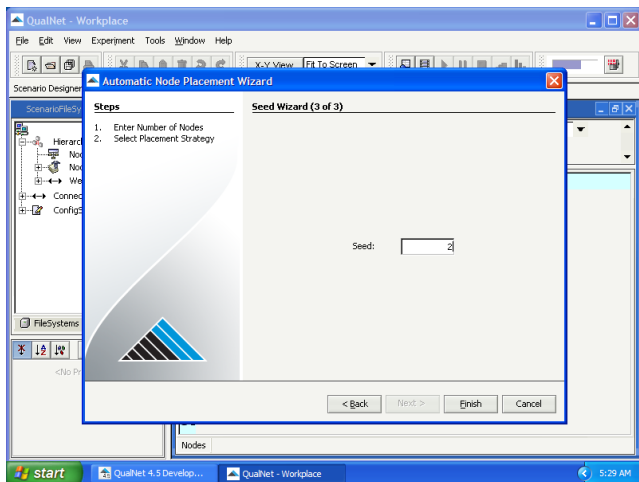
# Large Networks (cont'd)

- **Seed** – an integer used to set the starting point for generating a series of random numbers



# Large Networks (cont'd)

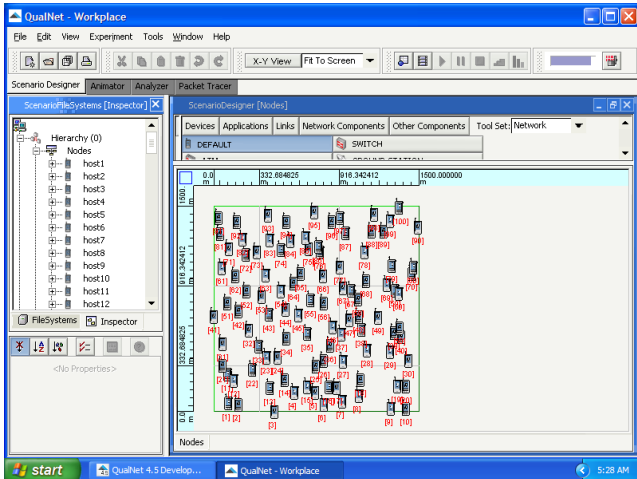
- Another seed value





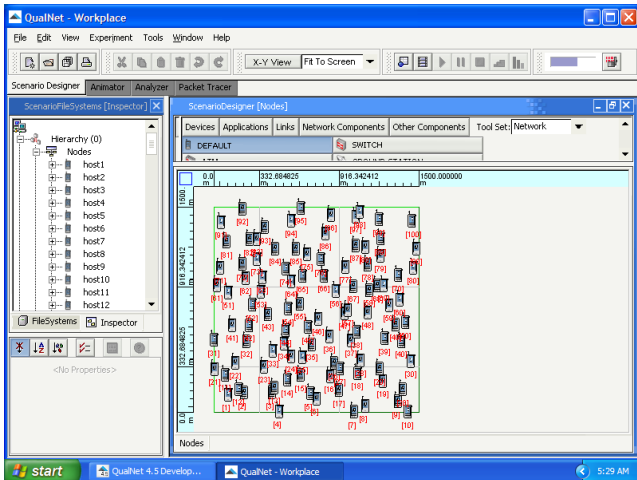
# Large Networks (cont'd)

- Uniform, seed = 1



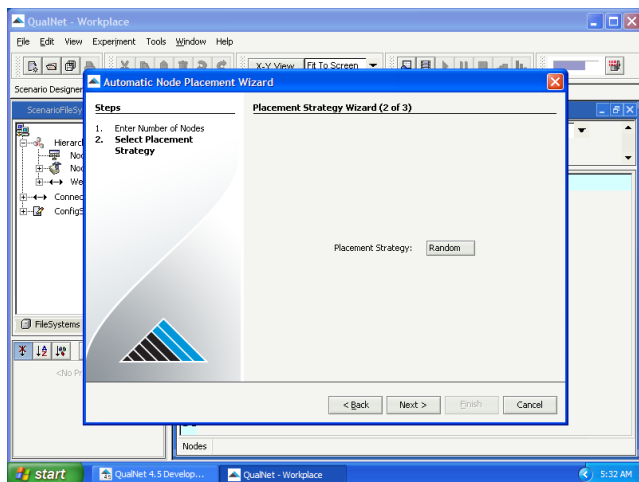
# Large Networks (cont'd)

- Uniform, seed = 2



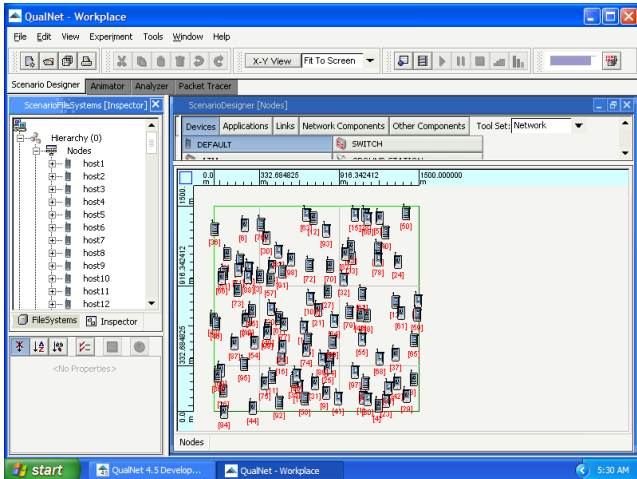
# Large Networks (cont'd)

- Placement strategy = random



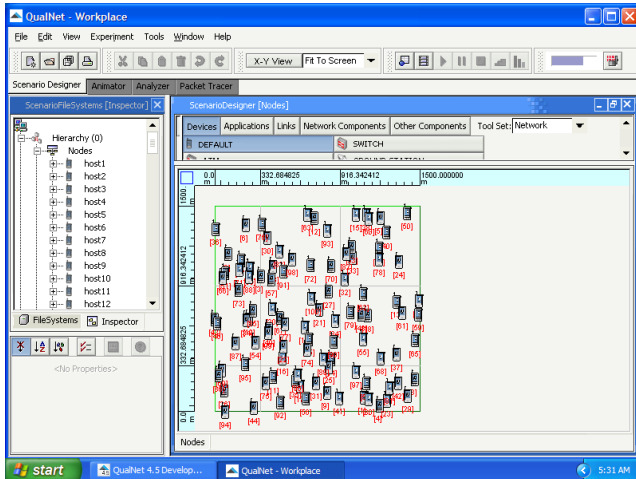
# Large Networks (cont'd)

- Random, seed = 3



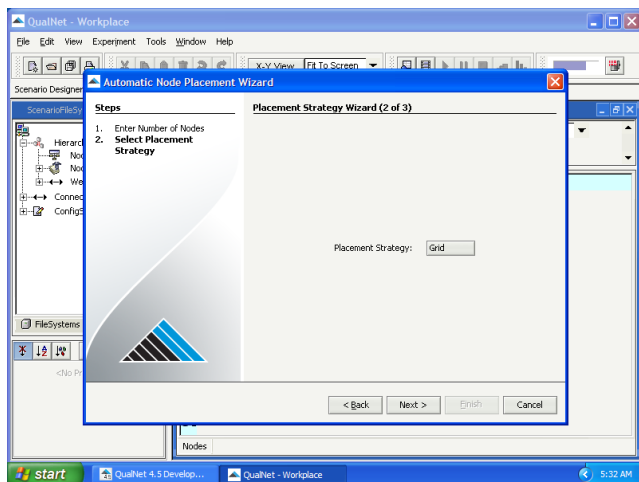
# Large Networks (cont'd)

- Random, seed = 3



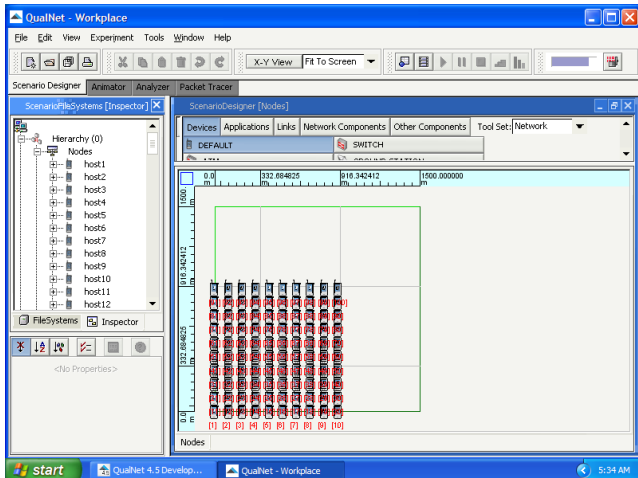
# Large Networks (cont'd)

- Placement strategy = grid



# Large Networks (cont'd)

- Nodes = 100, step = 100 m



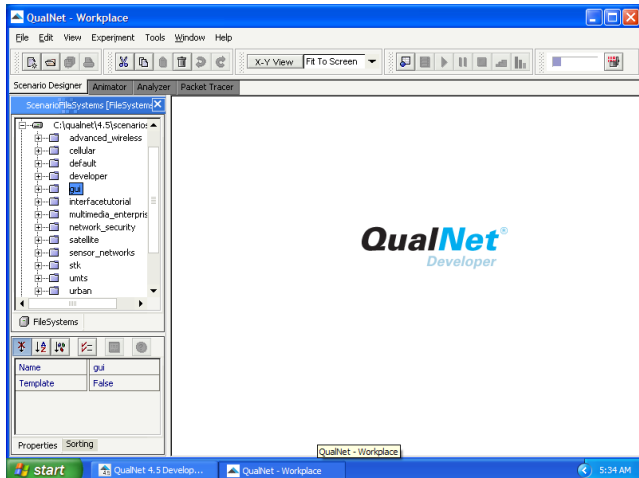
# Outline

- 1 Introduction
- 2 Installation of QualNet 4.5.1
- 3 Simulation workflow
- 4 Example 1
- 5 Example 2
- 6 Large networks
- 7 Sample scenarios**
- 8 Installation of QualNet 7.1



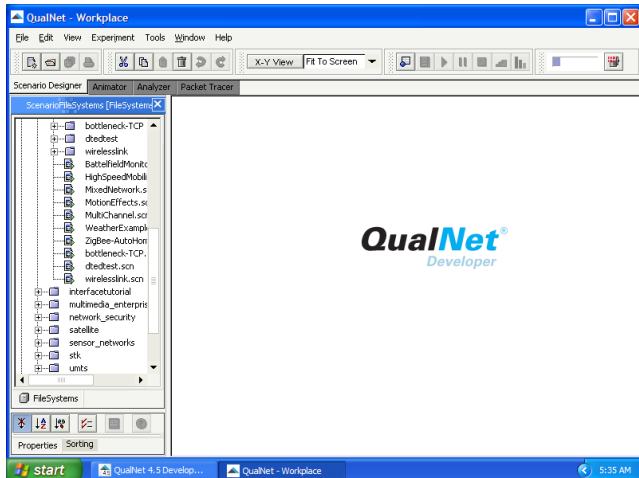
# Sample Scenarios

- QualNet includes a number of ready to use sample scenarios



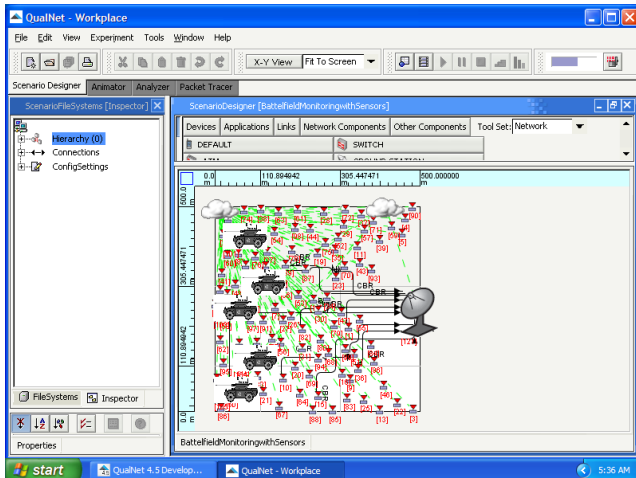
# Sample Scenarios (cont'd)

- Some features may require purchasing additional licenses



# Sample Scenarios (cont'd)

- **Battelfield Monitoring with Sensors:** scenario



# Sample Scenarios (cont'd)

- Battelfield Monitoring with Sensors: animation

The screenshot displays the QualNet software interface, titled "QualNet - Workplace". The main window is the "Animator Window [BattelfieldMonitoringwithSensors(run\_1)[Interactive]]", which shows a 2D plot of a battlefield. The plot features a grid with axes ranging from 0.0 to 500.0 meters. Numerous nodes are represented by small circles, each labeled with a coordinate pair (e.g., (1,1), (2,1), (3,1), etc.). A dense network of green lines connects these nodes, representing communication links. A single node at the bottom right is highlighted with a larger icon and labeled (1,1). The interface includes a menu bar (File, Edit, View, Experiment, Tools, Window, Help), a toolbar with various simulation controls, and a status bar at the bottom showing the system tray with the Windows logo, "QualNet 4.5 Develop...", "QualNet - Workplace", and the time "5:36 AM".

Execution Window [Runtime Insp...]

BattelfieldMonitoringwithSens...

Animator Window [BattelfieldMonitoringwithSensors(run\_1)[Interactive]]

Simulation Time: 1s:08fms:720us  
Real Time: 30h:00m:01s

Speed: [Slider]  
Progress: [Slider]

Animation Filters:  
Layers:  
Animation Commands:  
Node Mobil...

Output Window [BattelfieldMonitoringwithSensors(run\_1) - I/O]

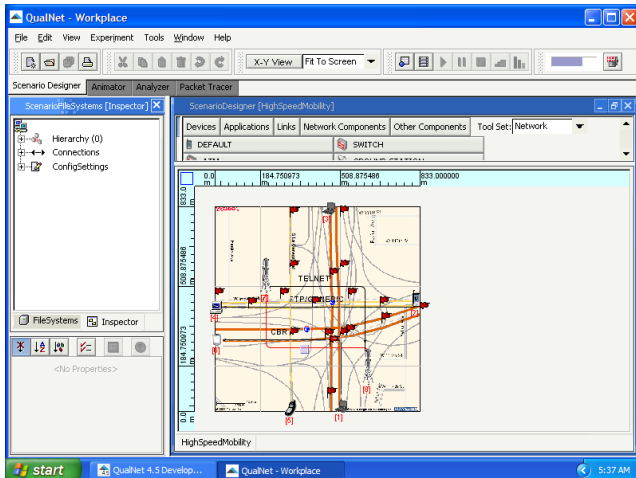
Current Sim Time[s] = 0.000000000 Real Time[s] = 0 Completed 0%

Output: BattelfieldMonitoringwithSensors(run\_1) - I/O

start QualNet 4.5 Develop... QualNet - Workplace 5:36 AM

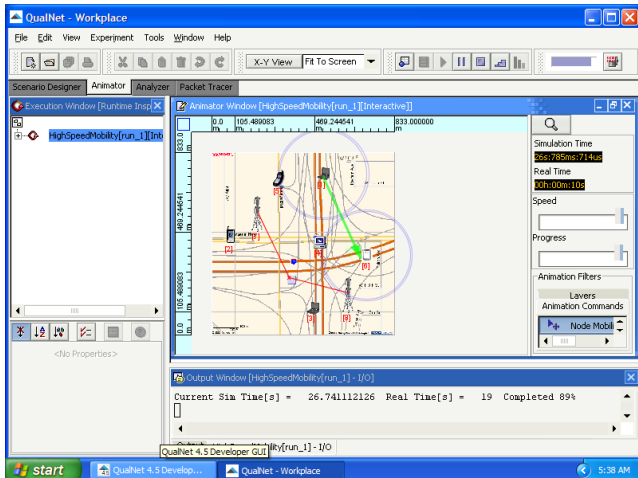
# Sample Scenarios (cont'd)

- **High-Speed Mobility:** scenario



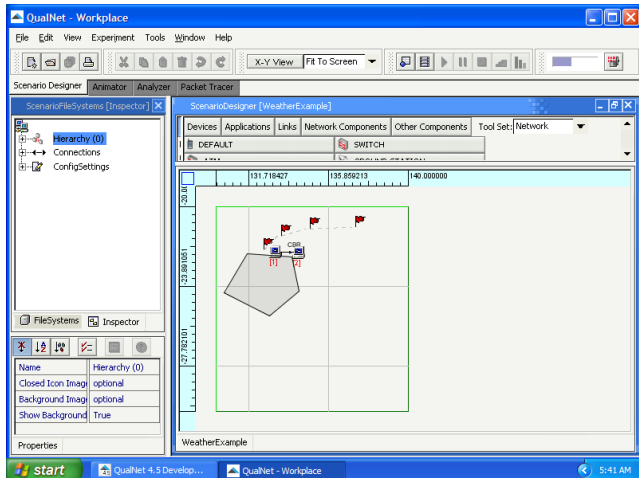
# Sample Scenarios (cont'd)

- High-Speed Mobility: animation



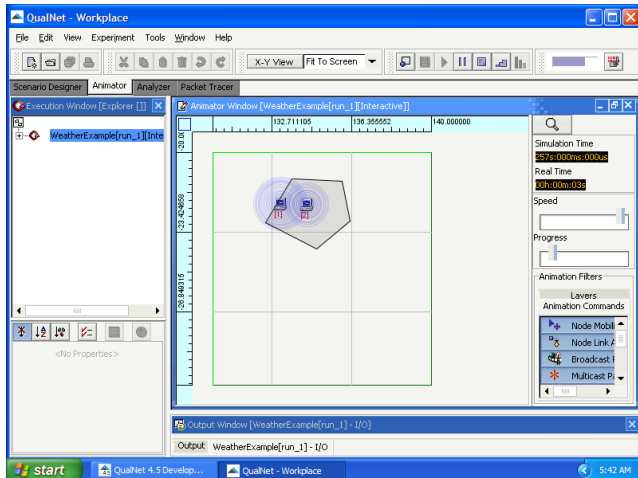
# Sample Scenarios (cont'd)

- Weather Example: scenario



# Sample Scenarios (cont'd)

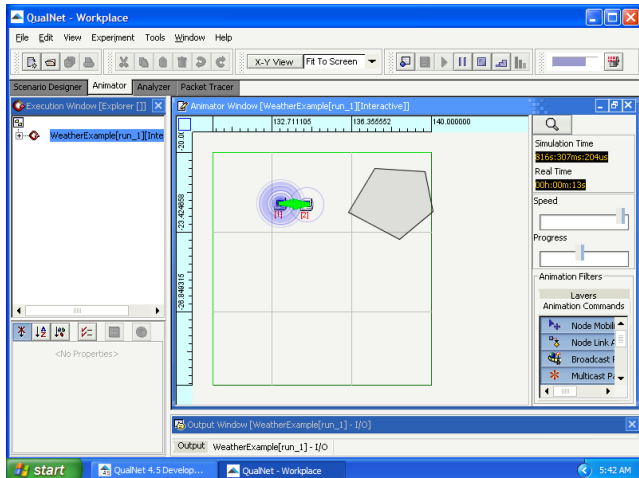
- Weather Example: animation





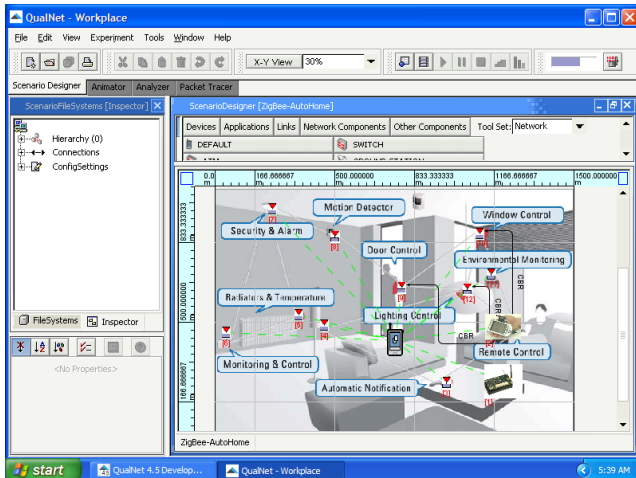
# Sample Scenarios (cont'd)

- Weather Example: animation



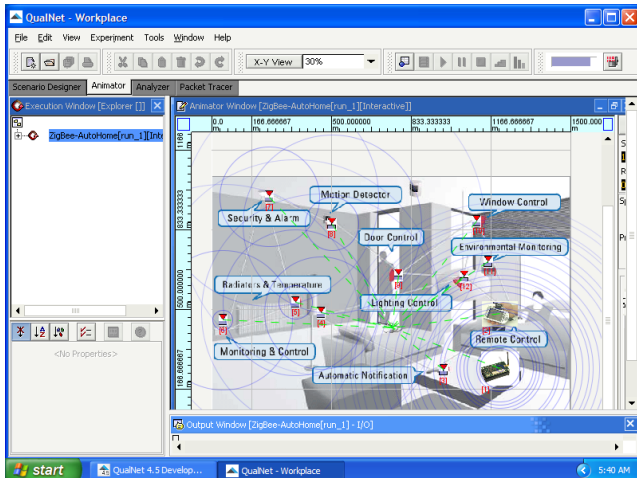
# Sample Scenarios (cont'd)

- ZigBee Auto Home: scenario



# Sample Scenarios (cont'd)

- ZigBee Auto Home: animation



# Outline

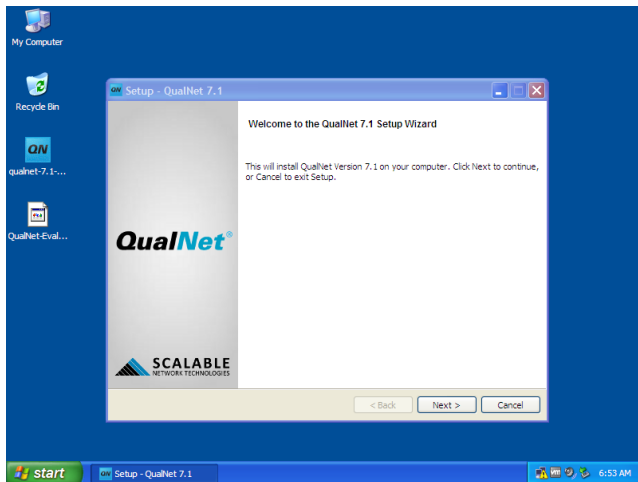
- 1 Introduction
- 2 Installation of QualNet 4.5.1
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# Installation of QualNet 7.1

- System requirements:
  - CPU: 32- or 64-bit
  - Memory: 2-4 GB
  - Disk: 1 GB free disk space
- Installation order:
  - 1 QualNet
  - 2 License

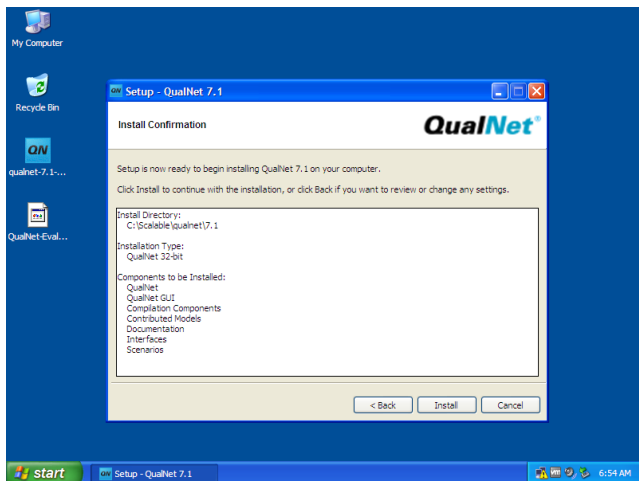
# Installation of QualNet 7.1 (cont'd)

- Install **QualNet 7.1**
  - qualnet-7\_1-windows-installer.exe



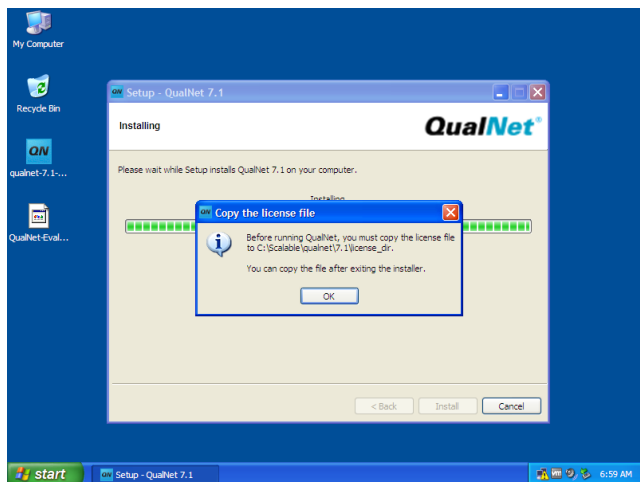
# Installation of QualNet 7.1 (cont'd)

- Components to be installed



# Installation of QualNet 7.1 (cont'd)

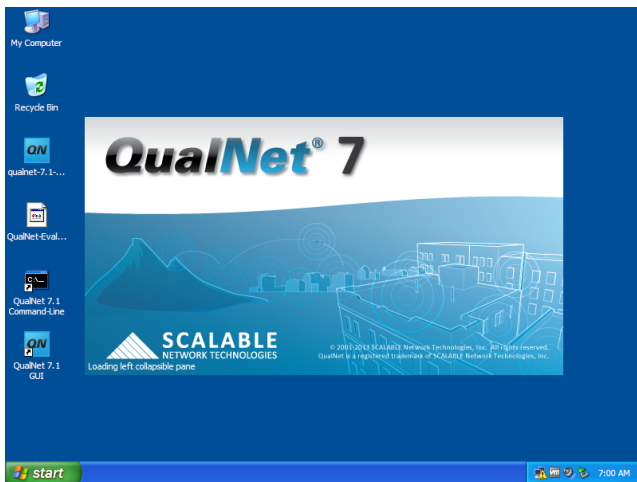
- Copy license file





# Installation of QualNet 7.1 (cont'd)

- Done!



# Installation of QualNet 7.1 (cont'd)

- QualNet 7.1 workspace

