

NetSim: Getting Started

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Outline of the Presentation

- Introduction to NetSim
- Installation Guidelines
- Help & Resources
- A Simple Network Simulation
- NetSim Simulation Libraries
- Simulation Results
- A Comparison with NS-3
- R&D with NetSim: RRM for WiFi



Introduction to NetSim

- **NetSim: A Simulation and Emulation Tool**

- Network Design and Planning
- Protocol and Network Modeling

- **Highlights**

- Cognitive Radio, LTE 5G, MANETs, VANETs, WLANs, WSNs, IoTs
- GUI
- Packet Animator
- Interface with Matlab, Wireshark and SUMO
- NetSim Emulator

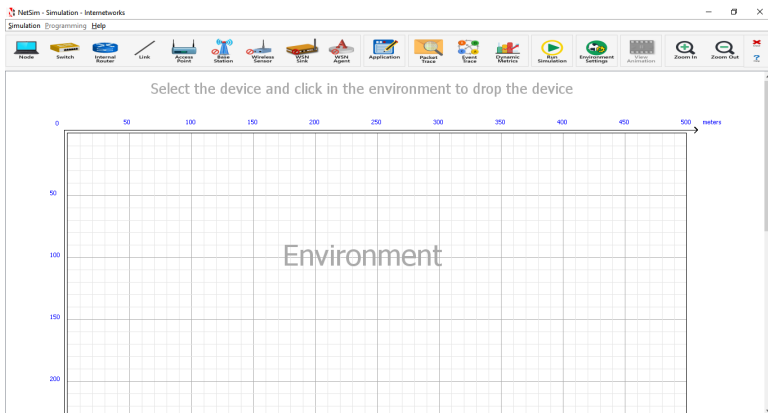
- **Applications**

- Network R&D and Academic Projects
- Focus on Defense Applications, Tactical Communications, Public Utility Networks



How is NetSim Used? Design the Network

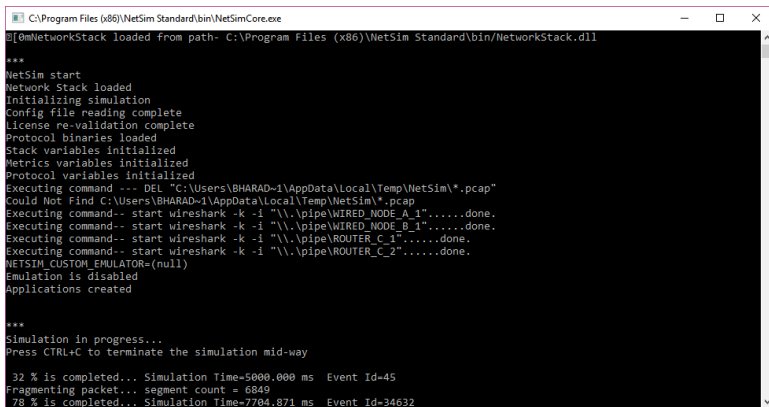
- Design the Network
 - using NetSim GUI or .XML config files



How is NetSim Used? Run the Simulation

- **Run the Simulation**

- from GUI or CLI
- log packet traces and event traces



```
C:\Program Files (x86)\NetSim Standard\bin\NetSimCore.exe
@[0mNetworkStack loaded from path- C:\Program Files (x86)\NetSim Standard\bin\NetworkStack.dll

***
NetSim start
Network Stack loaded
Initializing simulation
Config file reading complete
License re-validation complete
Protocol binaries loaded
Stack variables initialized
Metrics variables initialized
Protocol variables initialized
Executing command -- DEL "C:\Users\BHARAD~1\AppData\Local\Temp\NetSim\*.pcap"
Could Not Find C:\Users\BHARAD~1\AppData\Local\Temp\NetSim\*.pcap
Executing command-- start wireshark -k -i "\\.\pipe\WIRED_NODE_A_1".....done.
Executing command-- start wireshark -k -i "\\.\pipe\WIRED_NODE_B_1".....done.
Executing command-- start wireshark -k -i "\\.\pipe\ROUTER_C_1".....done.
Executing command-- start wireshark -k -i "\\.\pipe\ROUTER_C_2".....done.
NETSIM_CUSTOM_EMULATOR=(null)
Emulation is disabled
Applications created

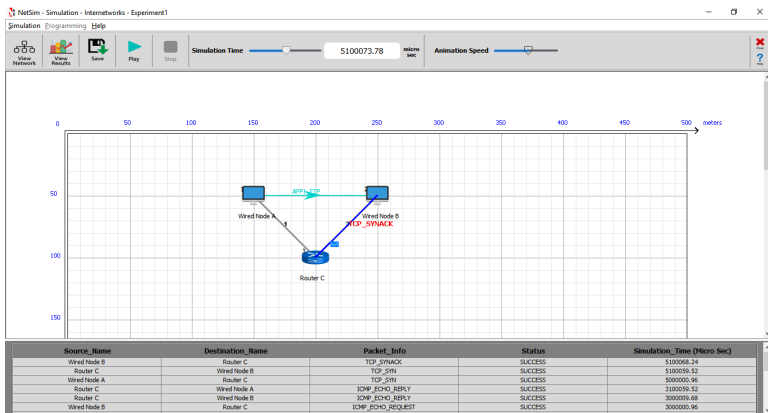
***
Simulation in progress...
Press CTRL+C to terminate the simulation mid-way

32 % is completed... Simulation Time=5000.000 ms Event Id=45
Fragmenting packet... segment count = 6849
78 % is completed... Simulation Time=7704.871 ms Event Id=34632
```



How is NetSim Used? Visualize using Packet Animator

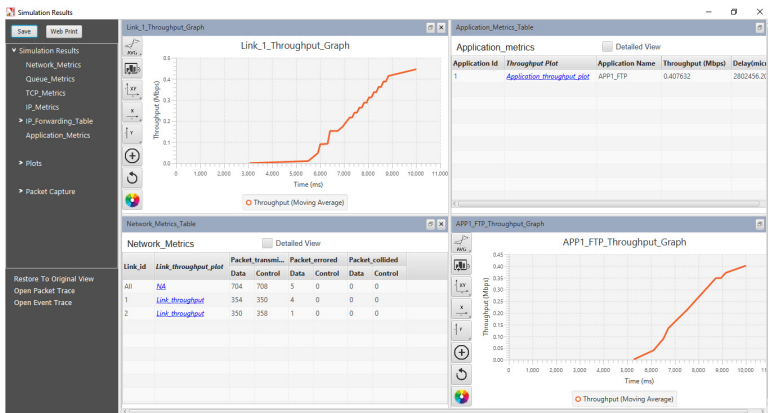
- Visualize the Simulation
 - using Packet Animator



How is NetSim Used? Analyse the Results

Analyse the Results

- application, queue, network, and protocol metrics at different layers
- available in different file formats for post processing

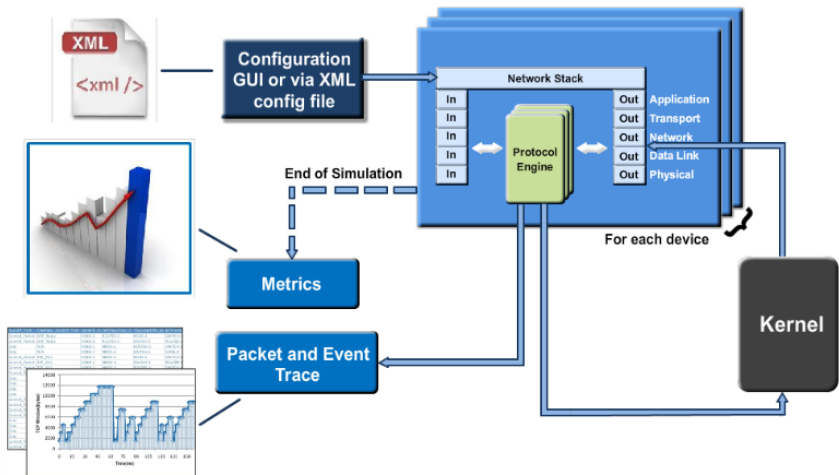


How is NetSim Used?

- **Design the Network**
 - using NetSim GUI or .XML config files
- **Run the Simulation**
 - from GUI or CLI
 - log packet traces and event traces
- **Visualize the Simulation**
 - using Packet Animator
- **Analyse the Results**
 - application, queue, network, and protocol metrics at different layers
 - available in different file formats for post processing
- **Develop your own Protocol/Algorithm**
 - modify or create algorithms and protocols
 - support for debug in IDE
- **Interface with External Software**
 - such as MATLAB, SUMO

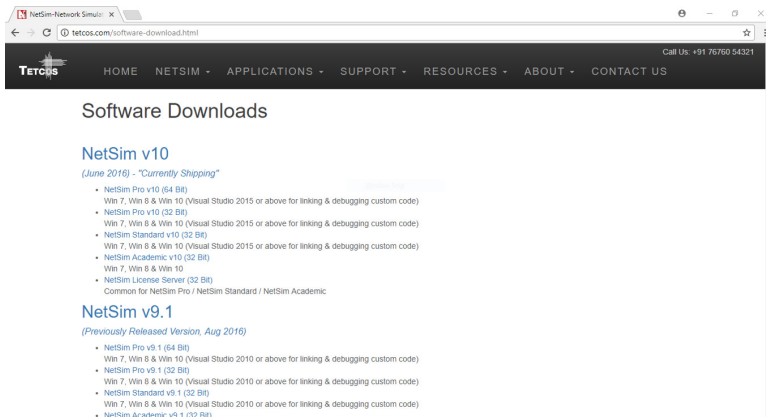


Introduction to NetSim: Simulator Framework



NetSim Installation: Download Executable File

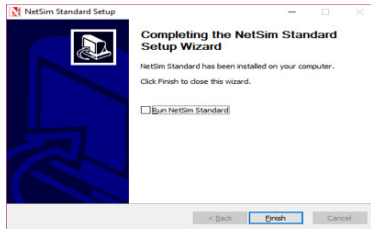
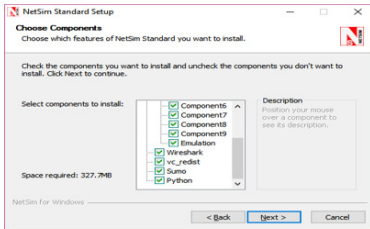
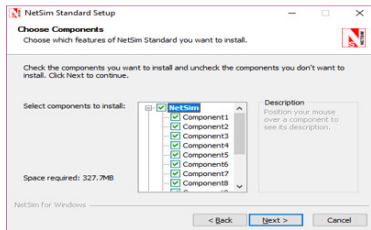
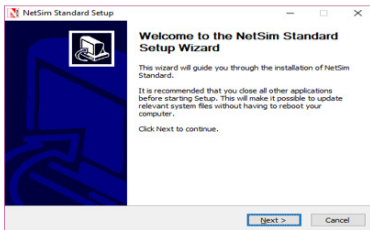
- Download NetSim Software Executable File (only for licensed users)
 - <http://www.tetcos.com/software-download.html>
 - Available as Pro, Standard and Academic versions
 - Requires Username and Password



NetSim Installation

• NetSim Installation

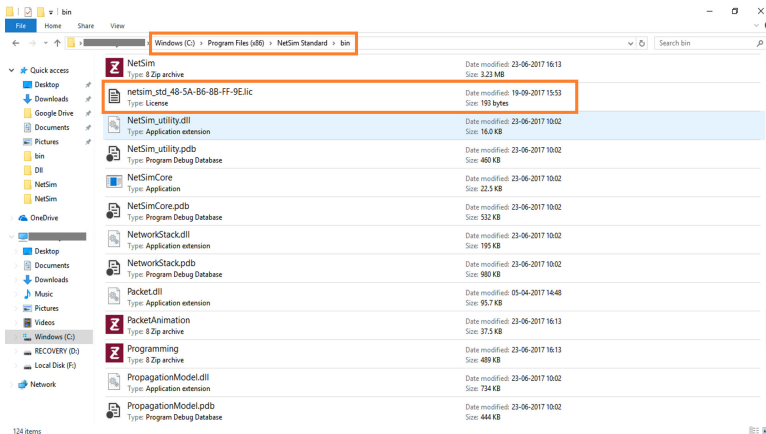
- Double Click .exe file (e.g., NetSim_Standard_10_32bit.exe)
- Install NetSim and Association Packages (WireShark, Python, etc)



NetSim Installation: Copy License File

• License

- Copy License File into the NetSim folder
(e.g., C:\Program Files(x86)\NetSim Standard\bin\)



NetSim Installation

- **Download NetSim Software Executable File**

- <http://www.tetcos.com/software-download.html>
- Available as Pro, Standard and Academic versions
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- **Installation**

- Double Click .exe file (e.g., NetSim_Standard_10_32bit.exe)
- Install NetSim and Association Packages (WireShark, Python, etc)

- **License**

- Copy License File into the NetSim folder
(e.g., C:\Program Files(x86)\NetSim Standard\bin\)

- **Launch NetSim**

- **Other Prerequisites**

- MS Visual Studio 2015 (for code modification)



- **NetSim Homepage** - <http://www.tetcos.com/>
 - Simulation Software Versions and Features
 - Download Page and Support
 - Documentation - User Manual, Experimental Manual, Help Files
 - List of Supported Technologies, Protocols and Algorithms
- **Simulator Information** - <https://tetcos.freshdesk.com/support/home>
 - FAQs, Getting Started
 - Modeling and Simulation, Emulation,
 - Cognitive radios, IoTs, WSNs, WLANs, LTE
- **NetSim Videos** - <https://www.youtube.com/user/Tetcos/videos>
 - Help, Webinars and Informational Videos
- **On Facebook** - <https://www.facebook.com/tetcosnetsim/>
- **On Twitter** - <https://twitter.com/tetcos?lang=en>



- **Getting Started**
 - Installation, About NetSim Environment, Simple Experiments
- **Illustrations by Examples**
 - Discusses All Network Protocols and Components
 - Details on Traffic Models and Generators
 - Details on Mobility Models
- **Measurements and Analysis**
 - Network Simulation Data Traces
 - Analysis with Pivot Tables, Wireshark, etc
 - Packet Animator
- **List of Advanced Features**
 - Writing Custom Code in NetSim
 - Interfacing with Matlab
- **Lists Known Issues and Solutions**



- Lists Experiments to Illustrate Network Protocols and Features
 - Performance of IoTs, MANETs, LTE, WiFi, ZigBee
 - TCP Connection Establishment and Congestion Control
 - IP Forwarding, Network Routing Protocols (OSPF, RIP)
 - Spanning Tree Algorithm
 - Legacy Networks such as ALOHA, CSMA
- Knowledge Base with Project Code -
<http://www.tetcos.com/file-exchange.html>



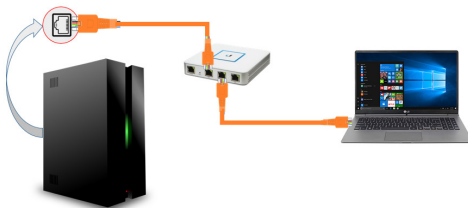
A Simple Experiment

- **Network Model and Scenario**

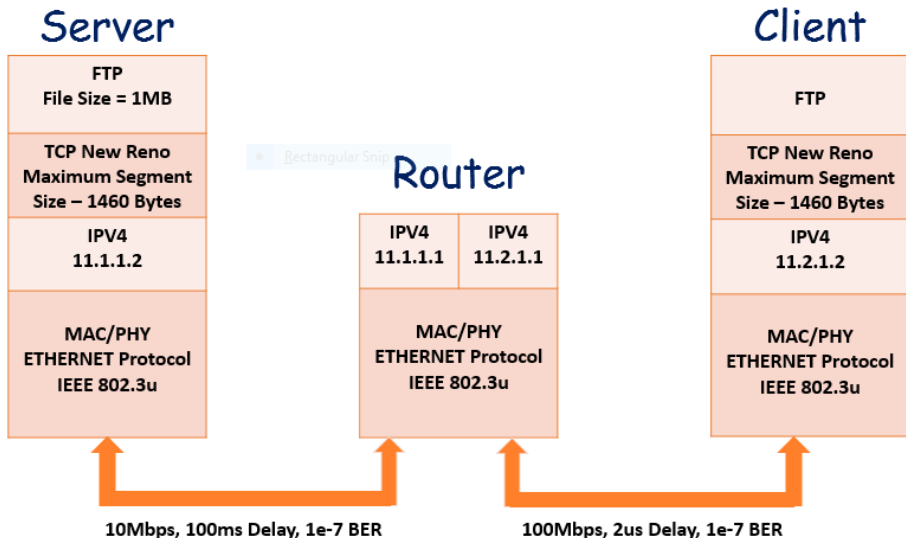
- FTP Application between a Server and a Client
- Wired Network Connection with Static Nodes

- **Performance Measure**

- File Download Throughput (in bits per second)
- Short-term Throughput (in bits per second)

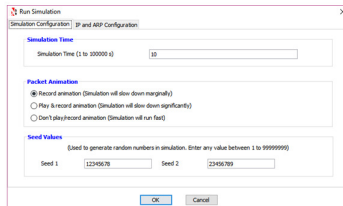
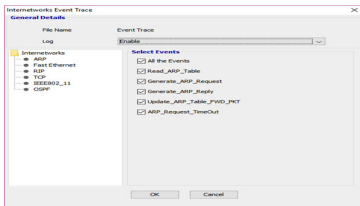
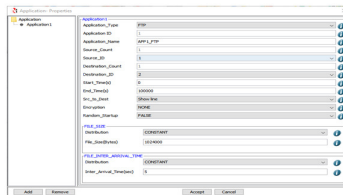
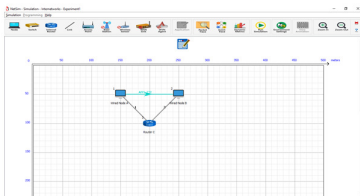


A Simple Experiment: Network Configuration



A Simple Experiment: NetSim Simulation

- Input via GUI or .XML (Enable Traces and Dynamic Metrics)
- Run Simulation (must specify Simulation Time)



- **Average Throughput @ Application Layer**

$$AT = \frac{(\text{Total Payload Delivered to Destination (in bytes)} * 8)}{\text{Simulation Time}}$$

- Fundamental Measure of Performance for Voice, Video or BE Traffic

- **Average Delay**

$$AD = \frac{\text{Sum of Delay of Successfully Delivered Packets}}{\text{Number of Successfully Delivered Packets}}$$

- Fundamental Measure of Performance for Voice, Transactions

- **Other Measures**

- Jitter (Voice)
- RSSI (Wireless Channels)
- Retransmission Counts (TCP, WiFi)
- Collision Probability (WiFi)



Application	FTP, HTTP, Email, Voice, Video, CBR, Custom
Transport	TCP ((Old) Tahoe, (New) Reno, Cubic), UDP
Network	OSPF, RIP, DSR, AODV, ZRP, OLSR, IPV4 Addressing
MAC/PHY	GSM, CDMA, LTE, LTE-A, WiFi, Ethernet, WRAN, TDMA, Aloha, CSMA/CD, Queueing and Scheduling (FIFO, WFQ, Priority)
Miscellaneous	Channel and Propagation Models, Mobility Models



Simulation Results: Data Files

- Simulation Output Files

- Metrics.xml, PacketTrace.csv, EventTrace.csv, Animation.txt, Node.pcap

```
<?xml version='1.0' encoding='ISO-8859-1'?>
<html>Metrics</html>
<!-- NETWORK METRICS -->
<MENU name='Network Metrics'/>
<TABLE name='Network Metrics'/>
<TR name='Link link_id' isShow='true'/>
<TR name='Link throughput plot' isShow='true'/>
<CTN name='Packet transmitted' isShow='true'/>
<CTN name='Data'/>
<CTN name='Control'/>
</TR>
<TR name='Packet errored' isShow='true'/>
<CTN name='Data'/>
<CTN name='Control'/>
</TR>
<TR name='Packet collided' isShow='true'/>
<CTN name='Data'/>
<CTN name='Control'/>
</TR>
<CTN name='Bytes transmitted(bytes)' isShow='false'/>
<CTN name='Bytes received(bytes)' isShow='false'/>
<CTN name='Overhead transmitted(bytes)' isShow='false'/>
<CTN name='Overhead received(bytes)' isShow='false'/>
<CTC Value='All'/>
<CTC Value='RM'/>
<CTC Value='Vegas'/>
<CTC Value='TCP'/>
<CTC Value='0'/>
<CTC Value='0'/>
<CTC Value='0'/>
```

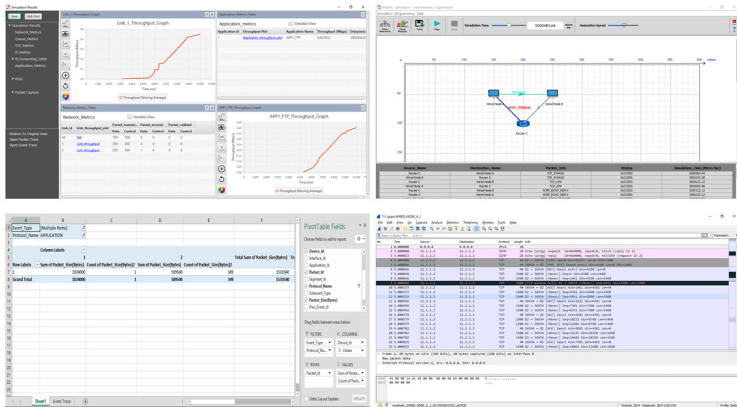
	A	B	C	D	E	F	G
1	Event_Id	Event_Type	Event_Time(us)	Device_Type	Device_Id	Interface_Id	Application_Id
2	4	APPLICATION_OUT	0	ROUTER	3	0	0
3	1	TIMER_EVENT	3000000	NODE	1	0	0
4	2	PHYSICAL_OUT	3000000	NODE	2	0	0
5	3	TIMER_EVENT	3000000	ROUTER	3	0	0
6	7	NETWORK_OUT	3000000	NODE	1	0	0
7	9	NETWORK_OUT	3000000	NODE	2	0	0
8	11	MAC_OUT	3000000	NODE	1	1	0
9	12	MAC_OUT	3000000	NODE	2	2	0
10	13	MAC_OUT	3000000	NODE	1	1	0
11	14	MAC_OUT	3000000	NODE	2	1	0
12	15	MAC_OUT	3000000.96	NODE	1	1	0
13	16	MAC_OUT	3000000.96	NODE	2	1	0
14	17	PHYSICAL_OUT	3000000.96	NODE	1	1	0
15	18	PHYSICAL_OUT	3000000.96	NODE	2	1	0
16	21	PHYSICAL_OUT	3000000.72	NODE	2	1	0
17	22	PHYSICAL_IN	3000000.72	ROUTER	3	2	0
18	23	MAC_IN	3000000.72	ROUTER	3	2	0
19	24	NETWORK_IN	3000000.72	ROUTER	3	2	0
20	25	NETWORK_OUT	3000000.72	ROUTER	3	0	0
21	26	MAC_OUT	3000000.72	ROUTER	3	2	0
22	27	MAC_OUT	3000000.72	ROUTER	3	2	0
23	28	MAC_OUT	3000000.68	ROUTER	3	2	0

	A	B	C	D	E	F	G	H
	PACKET_ID	BEHAVIOR_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APPP_NAME	SOURCE_IP	DESTINATION_IP	TRANSMITTER_IP	RECEIVER_IP
1	0/A	N/A	Control_Packet	ICMP_ECHO_REQUEST	NODE-1	ROUTER-1	NODE-1	NODE-1
2	0/A	N/A	Control_Packet	ICMP_ECHO_REQUEST	NODE-2	ROUTER-1	NODE-2	ROUTER-1
3	0/A	N/A	Control_Packet	ICMP_ECHO_REPLY	ROUTER-1	NODE-3	ROUTER-3	NODE-1
4	0/A	N/A	Control_Packet	ICMP_ECHO_REPLY	ROUTER-3	NODE-1	ROUTER-1	ROUTER-3
5	0/A	N/A	Control_Packet	TCP_SYN	NODE-1	NODE-2	NODE-1	ROUTER-3
6	0/A	N/A	Control_Packet	TCP_SYN	NODE-1	NODE-2	ROUTER-3	NODE-2
7	0/A	N/A	Control_Packet	TCP_SYNACK	NODE-2	NODE-1	NODE-2	ROUTER-3
8	0/A	N/A	Control_Packet	TCP_SYNACK	NODE-2	NODE-1	NODE-2	ROUTER-3
9	0/A	N/A	Control_Packet	TCP_ACK	NODE-1	NODE-2	NODE-1	ROUTER-3
10	1	1	1 FTP	APPI_FTP	NODE-1	NODE-2	NODE-2	ROUTER-3
11	1	1	1 FTP	APPI_FTP	NODE-1	NODE-2	ROUTER-1	NODE-1
12	1	1	3 FTP	APPI_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3
13	0/A	N/A	Control_Packet	TCP_ACK	NODE-1	NODE-2	ROUTER-3	NODE-2
14	1	1	1 FTP	APPI_FTP	NODE-1	NODE-2	ROUTER-3	NODE-2
15	1	1	1 FTP	APPI_FTP	NODE-2	NODE-1	ROUTER-3	NODE-2
16	1	1	1 FTP	APPI_FTP	NODE-2	NODE-1	ROUTER-3	NODE-2
17	0/A	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
18	1	1	2 FTP	APPI_FTP	NODE-1	NODE-2	ROUTER-3	NODE-4
19	1	1	2 FTP	APPI_FTP	NODE-2	NODE-1	ROUTER-3	ROUTER-3
20	0/A	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
21	1	1	1 FTP	APPI_FTP	NODE-1	NODE-2	ROUTER-3	NODE-4
22	0/A	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	ROUTER-3
23	0/A	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1

[illegible]

Simulation Results: Data Analysis

- Data Analysis
 - Results Dashboard, Packet Animator, Pivot Tables, Wireshark



- **Simulation Output**
 - Metrics.xml, PacketTrace.csv, EventTrace.csv, Animation.txt, Node.pcap
- **Data Analysis**
 - Results Dashboard, Packet Animator, Pivot Tables, Wireshark
- **NetSim permits Analytics of Multiple Experiments**



Simulation Results - Metrics

Network/Link Metrics	Data and Control Packets - Tx, Rx, Errored, Payload and Overheads
Queue Metrics	Queued, Dequeued, Dropped
Device Metrics	ARP Table, IP Forwarding Table
Protocol Metrics	TCP (Segments Transmitted, ACKs Received, Retransmissions), IP related
Application Metrics	Packets Transmitted and Received, Payload Transmitted and Received, Throughput and Delay



Simulation Results - Metrics - Results Dashboard

Simulation Results

Save Web Print

Simulation Results

- Network_Metrics
- Queue_Metrics
- TCP_Metrics
- IP_Metrics
- IP_Forwarding_Table
- Application_Metrics
- Plots
- Packet Capture

Restore To Original View
Open Packet Trace
Open Event Trace

Queue_Metrics_Table

Queue_Metrics

Detailed View

Device_id	Port_id	Queued_packet	Dequeued_packet	Dropped_packet
3	1	353	353	0
3	2	355	355	0

Application_Metrics_Table

Application_metrics

Detailed View

Application Id	Throughput Plot	Application Name	Throughput (Mbps)	Delay(microsec)
1	Application throughput plot	APP1_FTP	0.407632	2802456.20

IP_Metrics_Table

IP_Metrics

Detailed View

Device Id	Packet sent	Packet forwarded	Packet received
1	359	0	342
2	353	0	351
3	708	708	0

Network_Metrics_Table

Network_Metrics

Detailed View

Link_id	Link_throughput_plot	Packet_transmitted	Packet_errored	Packet_collided			
		Data	Control	Data	Control	Data	Control
All	NA	704	708	5	0	0	0
1	Link throughput	354	350	4	0	0	0
2	Link throughput	350	358	1	0	0	0

TCP_Metrics_Table

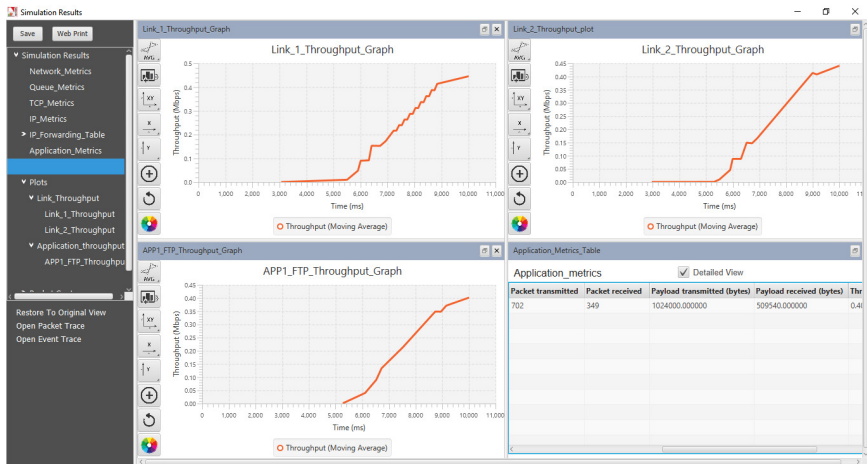
TCP_Metrics

Detailed View

Source	Destination	Segment Sent	Segment Received	Ack Sent	Ack Received
WIRED NODE A	ANY_DEVICE	0	0	0	0
WIRED NODE B	ANY_DEVICE	0	0	0	0
ROUTER C	ANY_DEVICE	0	0	0	0
WIRED NODE A	WIRED NODE B	349	0	1	341
WIRED NODE B	WIRED NODE A	0	349	349	1



Simulation Results - Metrics - Results Dashboard



Simulation Results - Packet Traces

- Trace of a Packet in the Network
 - Trace is saved as a Spread Sheet

	A	B	C	D	E	F	G	H
1	PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
2	0	N/A	Control_Packet	ICMP_ECHO_REQUEST	NODE-1	ROUTER-3	NODE-1	ROUTER-3
3	0	N/A	Control_Packet	ICMP_ECHO_REQUEST	NODE-2	ROUTER-3	NODE-2	ROUTER-3
4	0	N/A	Control_Packet	ICMP_ECHO_REPLY	ROUTER-3	NODE-2	ROUTER-3	NODE-2
5	0	N/A	Control_Packet	ICMP_ECHO_REPLY	ROUTER-3	NODE-1	ROUTER-3	NODE-1
6	0	N/A	Control_Packet	TCP_SYN	NODE-1	NODE-2	NODE-1	ROUTER-3
7	0	N/A	Control_Packet	TCP_SYN	NODE-1	NODE-2	ROUTER-3	NODE-2
8	0	N/A	Control_Packet	TCP_SYNACK	NODE-2	NODE-1	NODE-2	ROUTER-3
9	0	N/A	Control_Packet	TCP_SYNACK	NODE-2	NODE-1	ROUTER-3	NODE-1
10	0	N/A	Control_Packet	TCP_ACK	NODE-1	NODE-2	NODE-1	ROUTER-3
11	1	1	FTP	APP1_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3
12	1	2	FTP	APP1_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3
13	1	3	FTP	APP1_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3
14	0	N/A	Control_Packet	TCP_ACK	NODE-1	NODE-2	ROUTER-3	NODE-2
15	1	1	FTP	APP1_FTP	NODE-1	NODE-2	ROUTER-3	NODE-2
16	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	NODE-2	ROUTER-3
17	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
18	1	2	FTP	APP1_FTP	NODE-1	NODE-2	ROUTER-3	NODE-2
19	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	NODE-2	ROUTER-3
20	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
21	1	3	FTP	APP1_FTP	NODE-1	NODE-2	ROUTER-3	NODE-2
22	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	NODE-2	ROUTER-3
23	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
24								



- Trace of a Packet in the Network
 - Trace is saved as a Spread Sheet
- Items Listed in Packet Trace
 - Packet ID, Segment ID, Packet Type
 - Source ID, Destination ID, Transmitter ID, Receiver ID
 - IN and OUT Times in the Network Stack
- Data Analysis
 - PivotTables are Effective to Analyze Measurement Data
 - See User Manual for Help
- Measurements and Metrics
 - Throughput, Delay, Jitter
 - Average, Max, Min Measurements



Simulation Results - Event Traces

- Record of All Events in the Network and Stacks
 - Packet IN and OUT Events in the Network Stack
 - Events related to Protocols - Schedule, Backoff, Timeouts, etc
 - Trace is saved as a Spread Sheet

	A	B	C	D	E	F	G	H
1	Event_Id	Event_Type	Event_Time(US)	Device_Type	Device_Id	Interface_Id	Application_Id	Packet_Id
2	4	APPLICATION_OUT	0	ROUTER	3	0	0	0
3	1	TIMER_EVENT	3000000	NODE	1	0	0	0
4	2	TIMER_EVENT	3000000	NODE	2	0	0	0
5	3	TIMER_EVENT	3000000	ROUTER	3	0	0	0
6	7	NETWORK_OUT	3000000	NODE	1	0	0	ICMP_ECHO_REQUEST
7	9	NETWORK_OUT	3000000	NODE	2	0	0	ICMP_ECHO_REQUEST
8	11	MAC_OUT	3000000	NODE	1	1	0	0
9	12	MAC_OUT	3000000	NODE	2	1	0	0
10	13	MAC_OUT	3000000	NODE	1	1	0	0
11	14	MAC_OUT	3000000	NODE	2	1	0	0
12	15	MAC_OUT	3000000.96	NODE	1	1	0	0
13	16	MAC_OUT	3000000.96	NODE	2	1	0	0
14	17	PHYSICAL_OUT	3000000.96	NODE	1	1	0	ICMP_ECHO_REQUEST
15	18	PHYSICAL_OUT	3000000.96	NODE	2	1	0	ICMP_ECHO_REQUEST
16	21	PHYSICAL_OUT	3000006.72	NODE	2	1	0	0
17	22	PHYSICAL_IN	3000008.72	ROUTER	3	2	0	ICMP_ECHO_REQUEST
18	23	MAC_IN	3000008.72	ROUTER	3	2	0	ICMP_ECHO_REQUEST
19	24	NETWORK_IN	3000008.72	ROUTER	3	2	0	ICMP_ECHO_REQUEST
20	25	NETWORK_OUT	3000008.72	ROUTER	3	0	0	ICMP_ECHO_REPLY
21	26	MAC_OUT	3000008.72	ROUTER	3	2	0	0
22	27	MAC_OUT	3000008.72	ROUTER	3	2	0	0



Simulation Results - Event Traces

- **Record of All Events in the Network and Stacks**
 - Packet IN and OUT Events in the Network Stack
 - Events related to Protocols - Schedule, Backoff, Timeouts, etc
 - Trace is saved as a Spread Sheet
- **Items Listed in Event Trace**
 - Time Stamp, Event ID, Event Type, Device Type and ID, Protocol Name, Packet Details, etc
 - Additional Data for Debugging
- **Data Analysis**
 - PivotTables are Effective to Analyze Measurement Data
 - See User Manual for Help
- **Measurements and Metrics**
 - Packet Metrics such as Throughput, Delay, Jitter
 - Protocol Metrics and Device Metrics



Data Analysis with PivotTables*

	A	B	C	D	E	F	G	H
1	PACKET_ID	SEGMENT_ID	PACKET_TYPE	CONTROL_PACKET_TYPE/APP_NAME	SOURCE_ID	DESTINATION_ID	TRANSMITTER_ID	RECEIVER_ID
2	0	N/A	Control_Packet	ICMP_ECHO_REQUEST	NODE-1	ROUTER-3	NODE-1	ROUTER-3
3	0	N/A	Control_Packet	ICMP_ECHO_REQUEST	NODE-2	ROUTER-3	NODE-2	ROUTER-3
4	0	N/A	Control_Packet	ICMP_ECHO_REPLY	ROUTER-3	NODE-2	ROUTER-3	NODE-2
5	0	N/A	Control_Packet	ICMP_ECHO_REPLY	ROUTER-3	NODE-1	ROUTER-3	NODE-1
6	0	N/A	Control_Packet	TCP_SYN	NODE-1	NODE-2	NODE-1	ROUTER-3
7	0	N/A	Control_Packet	TCP_SYN	NODE-1	NODE-2	ROUTER-3	NODE-2
8	0	N/A	Control_Packet	TCP_SYNACK	NODE-2	NODE-1	NODE-2	ROUTER-3
9	0	N/A	Control_Packet	TCP_SYNACK	NODE-2	NODE-1	ROUTER-3	NODE-1
10	0	N/A	Control_Packet	TCP_ACK	NODE-1	NODE-2	NODE-1	ROUTER-3
11	1	1	FTP	APP1_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3
12	1	2	FTP	APP1_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3
13	1	3	FTP	APP1_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3
14	0	N/A	Control_Packet	TCP_ACK	NODE-1	NODE-2	ROUTER-3	NODE-2
15	1	1	FTP	APP1_FTP	NODE-1	NODE-2	ROUTER-3	NODE-2
16	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	NODE-2	ROUTER-3
17	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
18	1	2	FTP	APP1_FTP	NODE-1	NODE-2	ROUTER-3	NODE-2
19	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	NODE-2	ROUTER-3
20	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
21	1	3	FTP	APP1_FTP	NODE-1	NODE-2	ROUTER-3	NODE-2
22	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	NODE-2	ROUTER-3
23	0	N/A	Control_Packet	TCP_ACK	NODE-2	NODE-1	ROUTER-3	NODE-1
24	1	4	FTP	APP1_FTP	NODE-1	NODE-2	NODE-1	ROUTER-3

Packet Trace



Data Analysis with Wireshark*

Wireshark - Packet 9: WIRED NODE A_1

Frame 9: 1500 bytes on wire (12000 bits), 1500 bytes captured (12000 bits) on *eth0*
 Encapsulation type: Raw IP (7)
 Arrival Time: Sep 26, 2017 20:00:33.200010000 India Standard Time
 [Time delta from capture epoch: 0.000000000 seconds]
 Epoch Time: 1485447577.200010000 seconds
 [Time delta from previous capture epoch: 0.000000000 seconds]
 [Time delta from previous displayed frame: 0.000000000 seconds]
 [Time since reference or first frame: 3.200100000 seconds]
 Frame Number: 9
 Frame Length: 1500 bytes (12000 bits)
 Capture Length: 1500 bytes (12000 bits)
 [Frame is ignored: False]
 [Frame is marked: False]
 [Protocols in frame: Raw IP (7)]
 [Coloring Rule Name: Raw IP (7)]
 [Coloring Rule String: tcp.analysis.flags BA [tcp.analysis.window_update]

Raw packet data

Internet Protocol Version 4, Src: 11.1.1.2, Dst: 11.2.1.2

... 0000 -> Version: 4
 ... 0000 -> Header Length: 20 bytes (5)
 ... 0000 -> Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)

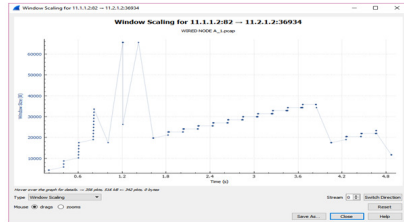
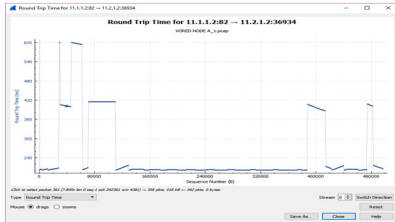
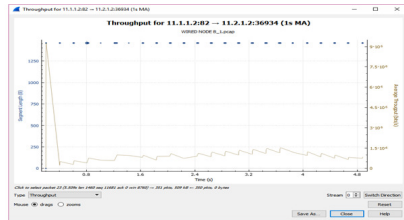
Total Length: 1500
 Identification: 0x0000 (0)

Flags: none
 Fragment offset: 0
 Time to live: 255
 Protocol: TCP (6)
 Header checksum: 0x0000 [validation disabled]
 Header checksum status: Unverified
 Source: 11.1.1.2
 Destination: 11.2.1.2
 [Source port: Unknown]
 [Destination port: Unknown]

Transmission Control Protocol, Src Port: 82, Dst Port: 36934, Seq: 2923, Len: 1400

Source Port: 82
 Destination Port: 36934
 [Sequence Number: 0]

File: 1 - Temp-300004 - Source: 11.1.1.2 - Destination: 11.2.1.2 - Protocol: TCP - Length: 1500 - Info: [TCP Window Full] 82 -> 36934 [Seq=2923 Win=1400 Len=1400]



A Comparison with NS-3

	NetSim	NS-3
Installation	Easy	Easy
Input	GUI or CLI	Script File
Output	Trace Files & Results Dashboard	Trace Files Only
Libraries	Extensive	Extensive
Animation	Packet Animator	NetAnim
Support	Essential Documentation & Support Team	Extensive Documentation & Google Groups
Correctness	Verified Regularly by Support Team	Ensured by NS-3 Users
Difficulty	Easy for Beginners	Comparable for Complex Networks



- **WiFi Standards Focus on Wireless Access and Management of a BSS**
 - MAC: RTS/CTS, Backoff, etc
 - PHY: MCS, MIMO, etc
 - Management: Beacons, Authentication, Association, Mobility, etc
- **Performance Critically Depends on the Wireless Environment**
 - Interference can Limit Channel Access and Decrease Throughput
 - Poor Link Quality can lead to Slow Talker Problem
 - Network-wide Solutions Necessary for Optimal Operation
- **Radio Resource Management of WiFi Networks**
 - Focus on Management of the Wireless Environment
 - Channel Selection and Transmit Power Control @ APs
 - User Association @ Clients and APs



Transmit Power Control: An Illustration*

- **Transmit Power Control**

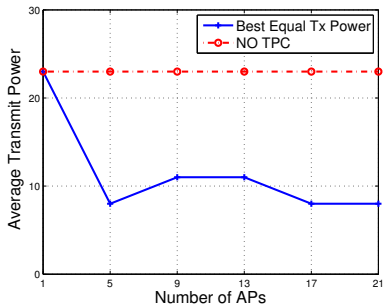
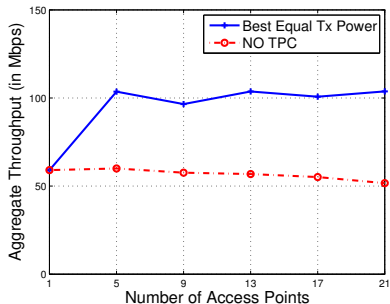
- Objective: Maximize Network Capacity
- Control: Transmit Power of Access Points

- **Simulation Environment**

- Topology: Linear (50 metres)
- WiFi Standard: IEEE 802.11ac
- Bandwidth: 20MHz
- Rate Adaptation: Minstrel
- Channel: Log Distance Propagation Loss Model with $\eta = 3.5$
- Max Transmit Power: 23dBm
- Min Transmit Power: 0dBm
- 2-3 Clients per AP
- Application: FTP (Downlink)



Transmit Power Control: An Illustration*



- Aggregate Network Throughput Increases with TPC
- Optimal Transmit Power Decreases with Density
- TPC Minimizes Interference and Enables Spatial Reuse



Network R&D with NetSim: Transmit Power Control

- **Transmit Power Control**
 - Effective in Increasing Network Capacity
 - Tradeoff between Capacity (Spatial Reuse) and Coverage
- **Challenges in Design**
 - A Distributed Algorithm for TPC
 - Dynamic and Adaptive Algorithm for Dynamic Wireless Environment
 - Support for Heterogeneous Devices and Standards
 - Limited Client Support
 - Other Network and Non-WiFi Interference
- **TPC Design with NetSim**
 - Limited Analytical Insights Available
 - Experimentation is Costly
 - Network Simulators are Effective Means to Study Performance



Questions!

