

# **Real-Time Graph Visualization Tool for Vehicular Ad-Hoc Networks**

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# **VIVAGr** - real time **VI**sualization tool for **V**ehicular **Ad**-hoc network connectivity **G**raphs

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## **Abstract:**

- ▶ Enables the effective synthesis of structural, topological, and dynamic VANET graphs
  - ▶ Given parameters that affect the shape and characteristics of a vehicular ad hoc network
    - *wireless range, mobility models, road-network topology, market penetration ratio, and exhibited interference*
- ▶ Present all active connections of the network in real-time mode using existing mobility traces
  - ▶ a visual encoding syntax is used to represent semantic meanings and highlight the effect of mobility and topology on vehicular network specific properties
- ▶ Allows researchers to explore and understand problems and issues related with vehicular ad-hoc networks

# Vehicular Ad-hoc NETWORKs (VANETs)

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- ▶ Ad hoc network composed of vehicles
  - ▶ self-organized communication networks
- ▶ Provide services and applications for
  - ▶ intelligent vehicle-to-vehicle and vehicle-to-infrastructure communications
- ▶ Challenging research topic
  - ▶ Individual nodes different from traditional wireless nodes
    - ▶ No power constraint
    - ▶ Nodes mostly mobile (high mobility of vehicles )
  - ▶ Road mobility constrains
  - ▶ Information exchange in VANETs occurs
    - ▶ at any time while vehicles are moving
    - ▶ in many small fragments, conveyed by nearby vehicles and static Road Side Units (RSUs)
  - ▶ Complement and extend existing networking infrastructure
  - ▶ Try to improve: active safety, traffic management

# Related work

	Penetration Ratio	Graph Analysis	Geographical Topology	Interference modeling	Real-Time animation of Mobility
Guess		v			
Pajek		v			v
Workbench		v			
LaNet-vi		v			
Vitan			v		
iNSpect		v	v		v
Multi-View			v		v
VIVAGr	v	v	v	v	v

- ▶ VIVAGr design approach differs from known graph visualization tool
  - ▶ Take in to account the various characteristics of a wireless vehicular ad hoc network
    - ▶ exhibited interference, transmission range, transmission power, transmission rate, RSU placement, market penetration ratio, mobility modes
  - ▶ Support informative (Real time) visualization
    - ▶ assist researchers to explore and understand problems and issues of VANETs
  - ▶ Show the effect of the properties of the networking environment in respect to
    - ▶ specific geographical areas and mobility patterns
  - ▶ Provide measures for graph analysis: structural and statistical

# Contribution

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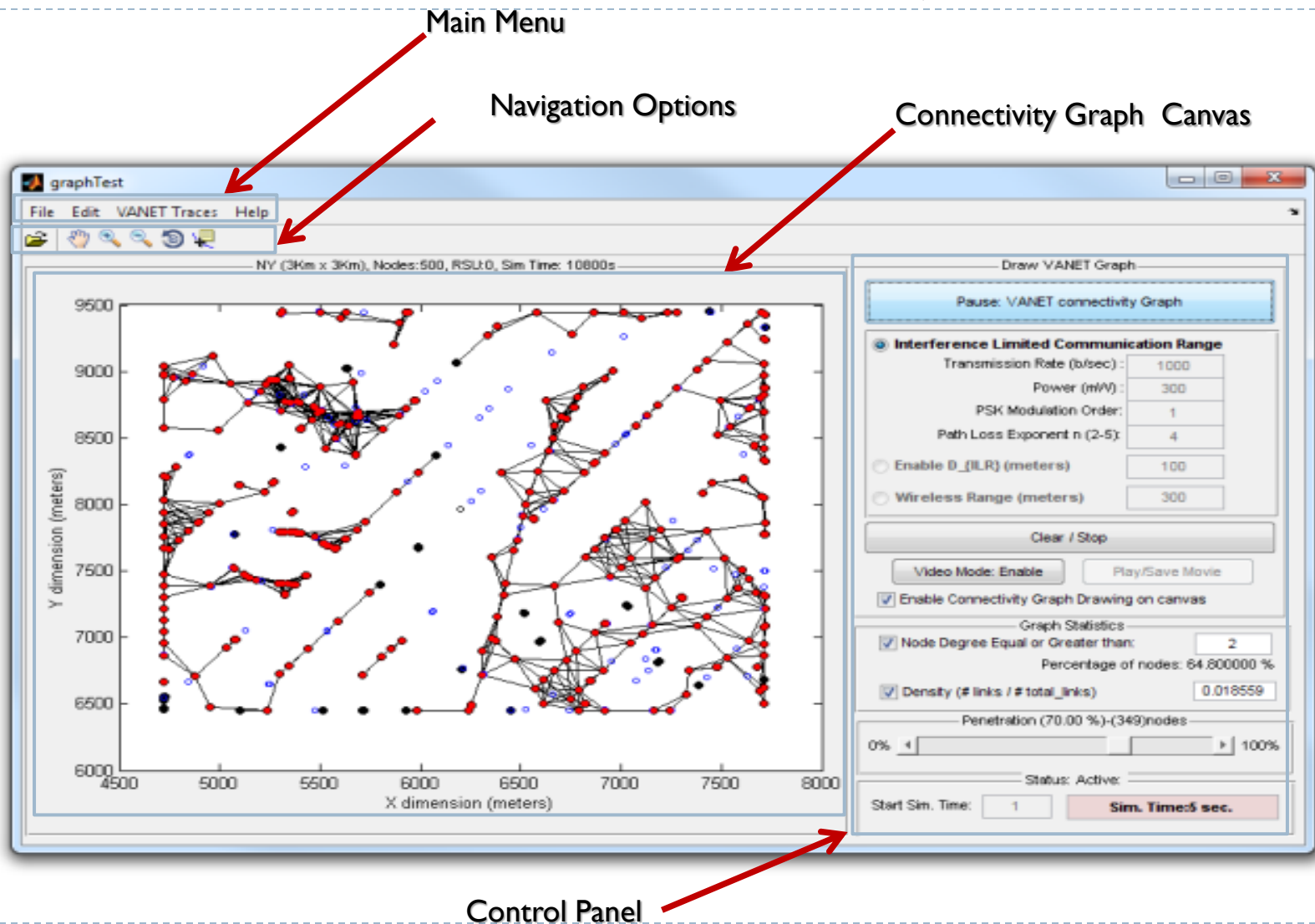
## ▶ VIVAGr allows users to

- ▶ Monitor in **real time** all corresponding changes in network topology and connectivity
- ▶ Control the networking conditions under which a link can be successfully formed given the properties of the underlying telecommunication system.
  - ▶ current implementation employs three different types of connectivity models:
    - wireless range
    - interference limited range
    - transmission rate mapping
- ▶ Calculate and represent specific properties and attributes of all vertices and/or edges of the graph
  - ▶ structural, topological, and dynamic characteristics of VANETs
- ▶ Control the time frame of operation, described by the mobility scenario
- ▶ Select the market penetration ratio of the network
- ▶ Record all the graph visualization processes, on the drawing canvas

- ▶ Imports mobility traces of vehicular nodes
- ▶ Creates the corresponding network connectivity graph in real-time mode
  - ▶ Highlighting all active connections of the network following the mobility patterns of vehicles over urban areas
  - ▶ A special visual encoding syntax used to represent semantic meanings for vehicular network connectivity
  - ▶ Highlight the effect of mobility and the underlying telecommunication system

# VIVAGr

(main screen)



# VIVAGr Design

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- ▶ Provides a link between formalism for representing network connectivity and graph visualization.
- ▶ VIVAGr is a portable, multiplatform, and modular tool
  - ▶ implemented in MATLAB (different operating platforms are supported)
- ▶ Includes various independent modules
  - ▶ used jointly or as separate functions
  - ▶ easily modified according to specific needs and requirements
- ▶ Designed and built for engineers and researchers



# Mobility Module

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- ▶ For the connectivity graph we need to import the related mobility information and pattern of vehicles
  - ▶ These information are described in pre-processed mobility trace files
  - ▶ A component able to transform these data into a structured common format for our tool was implemented and integrated with VIVAGr providing the:
    - ▶ nodes position from the beginning to the end of the mobility scenario in time
    - ▶ number of RSUs
    - ▶ size of the networking area
    - ▶ density of RSUs, ...
  - ▶ Different mobility traces can be imported to describe different mobility scenarios

# User Interface module

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- ▶ **Observe real time created graphs (and related changes) through the drawing canvas**
  - ▶ Enable navigation for changing the viewpoint of an object in the drawing scene
  - ▶ Allow smooth animated transitions following nodes mobility patterns and newly created or destroyed links
- ▶ **Control the real time visualization process given specific networking conditions and properties of the created VANET graph**
  - ▶ select different options for creating a connection networking graph
  - ▶ pause, stop, clear visualization, focus option (zoom in/out) on a specific region
  - ▶ monitor the selected statistical properties
  - ▶ enable and/or disable drawing (i.e. for fast statistics collection)
  - ▶ define market penetration ratio
  - ▶ formalize all user interaction commands in a VCR-style format
- ▶ **Enable video capture of the VANET network for later use and study**
- ▶ **Represent the graph/network semantics and**
  - ▶ Using specific visual encoding syntax
  - ▶ Highlight the effect of mobility and the underlying telecommunication system properties

# Connectivity Graph creation module

- ▶ ***Interference Limited Communication Range***
  - ▶ Allows the formation of links for which interference is the critical limiting factor for communication
  - ▶ Is affected by: the underlying telecommunication system:
    - ▶ Modulation scheme
    - ▶ Accepted target Bit Error Rate of the network
    - ▶ Systems' bandwidth
    - ▶ Transmission power
    - ▶ Propagation model that takes into account
      - degradation of transmission power in respect of distance,
      - shadowing and reflection effects
    - ▶ Transmission rate (*most importantly*)
- ▶ **Transmission rate mapping of all links**
  - ▶ For specific communication wireless range
  - ▶ A color map is then created for all links according to the achieved rate

Draw VANET Graph

Pause: VANET connectivity Graph

☒ **Interference Limited Communication Range**

Transmission Rate (b/sec) : 1000

Power (mW) : 300

PSK Modulation Order: 1

Path Loss Exponent n (2-5): 4

☐ Enable  $D_{ILR}$  (meters) 100

☐ Wireless Range (meters) 300

Clear / Stop

Video Mode: Enable Play/Save Movie

☒ Enable Connectivity Graph Drawing on canvas

Graph Statistics

☒ Node Degree Equal or Greater than: 2

Percentage of nodes: 64.800000 %

☒ Density (# links / # total\_links) 0.018559

Penetration (70.00 %)-(349)nodes

0% 100%

Status: Active:

Start Sim. Time: 1 Sim. Time: 5 sec.

# Graph Analysis module

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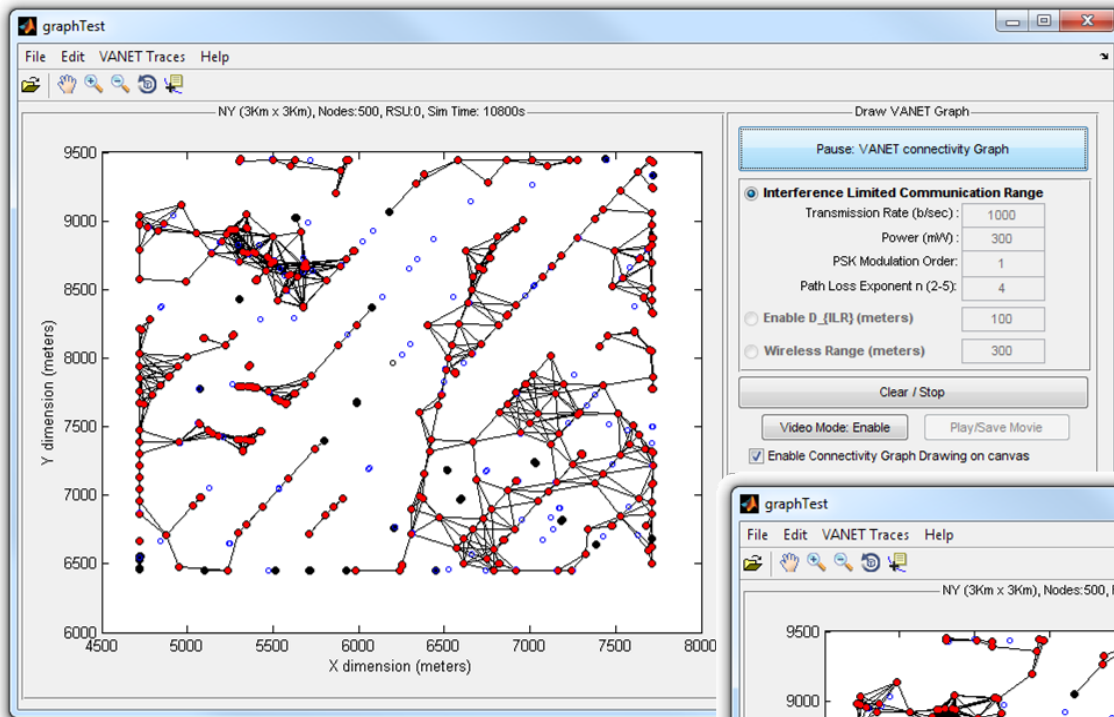
- ▶ Users can extract results on a number of metrics

- ▶ Node degree
- ▶ Effective Diameter
- ▶ Density
- ▶ Betweenness Centrality
- ▶ Lobby Index
- ▶ Link duration
- ▶ Connected periods
- ▶ Link re-healing time
- ▶ Number of clusters and communities

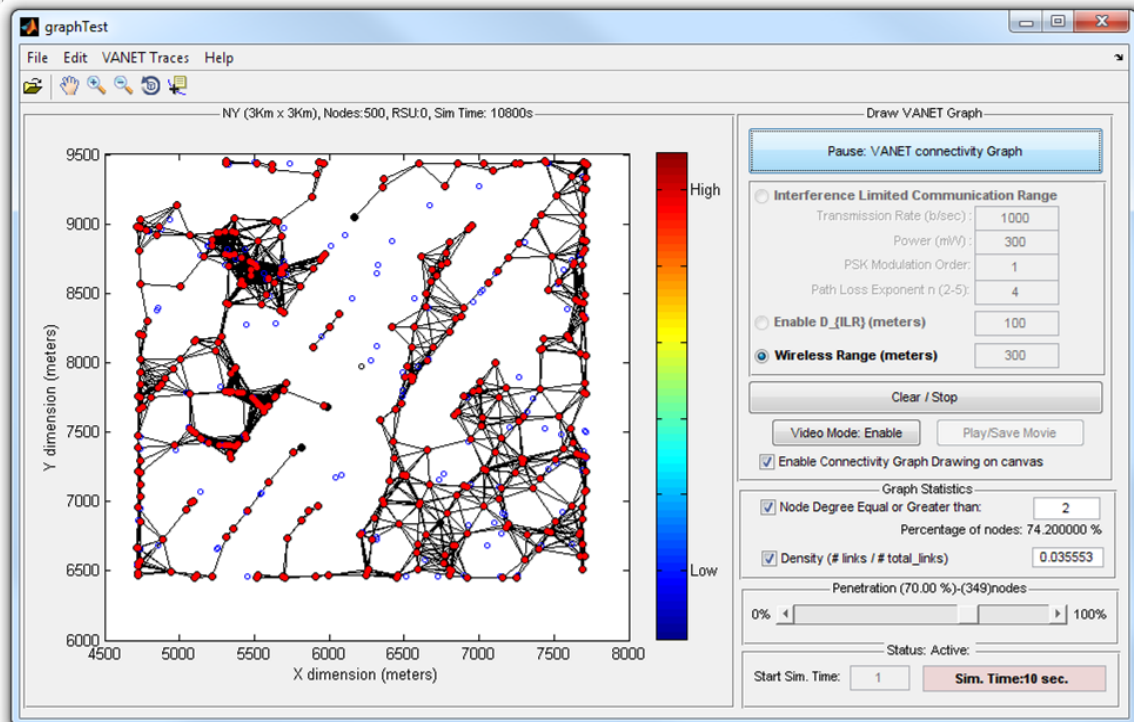
used to

- ▶ describe the shape and the properties of a vehicular network
  - ▶ identify the “highest-quality” vehicles in terms of connectivity
    - ▶ (i.e., nodes with high betweenness centrality/lobby index values)
  - ▶ identify the laws that govern the temporal evolution of VANET-graph properties
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- ▶ The tool can present them during the visualization process or to export structured data that could be analyzed in a later time using other graph analysis tools

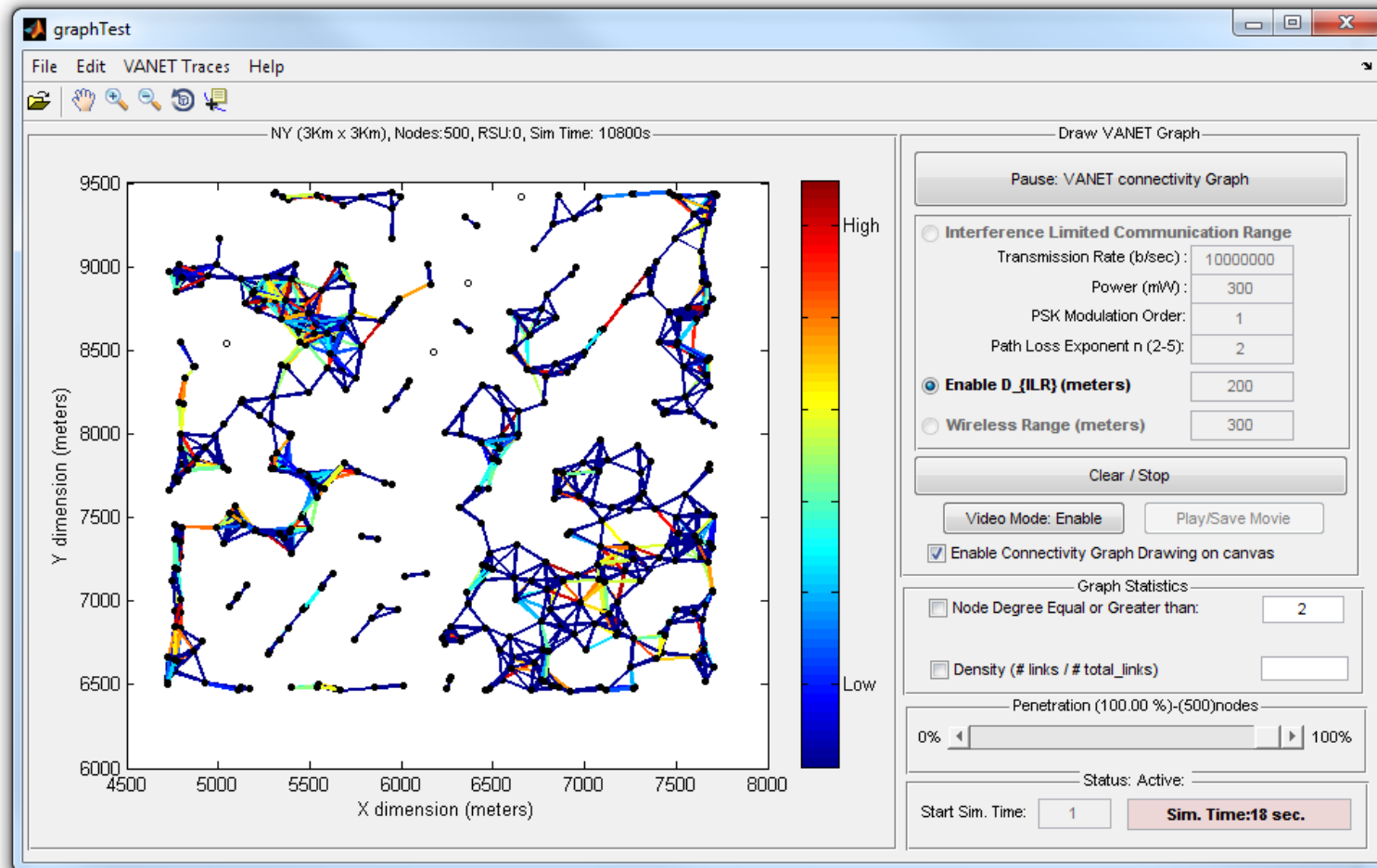
# Interference Limited Communication Range



Wireless Range



## Transmission Rate mapping of links

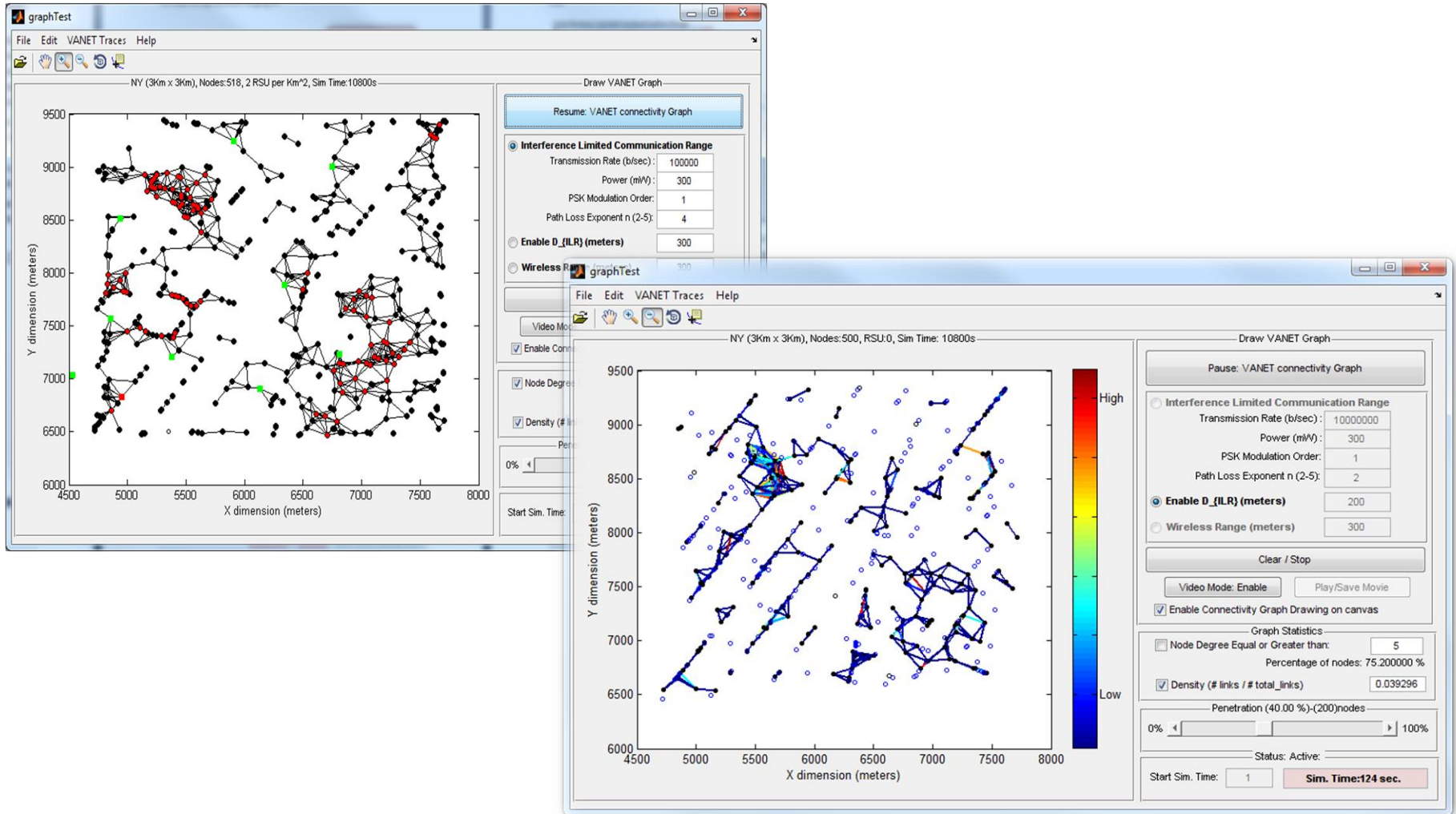


# Use-Case study

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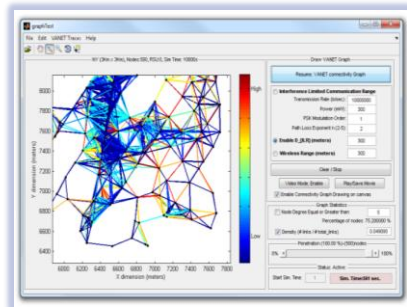
- ▶ **Mobility traces** : realistic mobility traces generated using the VanetMobiSim (two different vehicular mobility scenarios)
  - ▶ 3Km\*3Km area in upper-east Manhattan of New York (500 vehicles) and
  - ▶ 4Km\*4Km area in and around the city center of Los Angeles (700 vehicles)
  - VIVAGr module used to translate these mobility data into a structured MATLAB vector form and import back to the application
- ▶ **Navigation**
  - ▶ change the viewing angle and position on the drawing graph canvas and continue monitoring the animation of drawing graph in time.
- ▶ **Market Penetration (user defined)**
  - ▶ number of vehicles, physically located in the area of interest, able to actively participate in the formation of the VANET
  - ▶ vehicles that do not participate in the network are depicted with a different visual syntax and they only act as moving obstacles
  - our observations show that even when the penetration ratio is low, the created connectivity graphs, describing the set of feasible links, seem to follow the road map topology
- ▶ **Interference Limited Communication Range**
  - ▶ when interference phenomenon is taken into account, the connectivity and network density of the corresponding graph is much lower
  - we can increase network connectivity by forcing node to ensure **higher values for the interference limited communication range** and thus by select **lower transmission rate** to compensate with exhibited interference
  - node connectivity is affected by the road-map topology when we take into consideration the propagation loss factor and interference
- ▶ **Road Side Units**
  - ▶ RSUs influence the structure and evolution of the VANET communication graph
  - ▶ we annotate all stationary RSUs in the area of interest that inherit the properties similar to that of the vehicular nodes
  - by selecting the relative position and the density of RSU in the network we can result in different strategy for maximizing dissemination of information thus can be taken into account (i.e. maximize the number of serving nodes in time by the road side units)

# Use-Case study – example

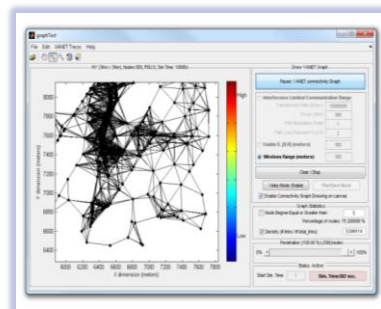




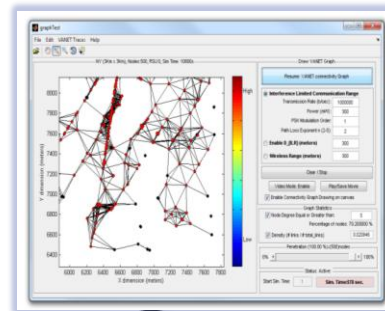
# Use-Case study – example



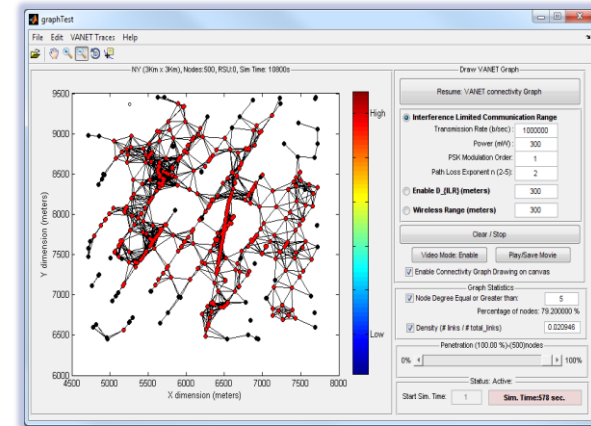
Zoom In



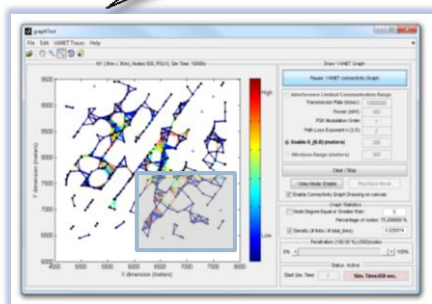
Select Wireless Range



Select Interference Limited Range and Node Degree > 5



Zoom Out



# Conclusion

VIVAGr allows researchers to observe:

- ▶ How the shape and behavior of vehicular communication network change due to mobility?
- ▶ How the underlying telecommunication systems affects the vehicular network topology?
- ▶ How the road-map topology affect the VANET properties?
- ▶ Which are the “highest-quality” vehicles in terms of connectivity?
- ▶ What are the laws that govern the temporal evolution of the network?
- ▶ What is the best deployment strategy for RSUs?

