Un esempio di modellizzazione mediante PN: moDElling MObile NEtworks

Presentazione

- Questa dispensa introduce il tool moDEling MObile NEtworks (DEMONE) con lo scopo di mostrare un'applicazione di modellizzazione mediante Reti di Petri
- E' costituita dalle presentazioni fatte in vari congressi (WAC2007, UWA 2008, SM 2009, ACCESS2010) e riviste (Int.l Journ on Multimedia Tech, 2011) internazionali a cui sono stati aggiunti commenti specifici per il corso

Introduzione a MANET (1)

- MANET (Mobile Ad-hoc NETwork) indica una tipologia di reti wireless che possono operare senza la necessità di una infrastruttura fisica fissa
  - le comunicazioni tra una sorgente e una destinazione sono stabilite e mantenute dalla cooperazione tra i vari host presenti nella rete
  - ogni host può agire
    - sia come end-point di una comunicazione (mittente/destinatario di msg)
    - che come router di pacchetti

Introduzione a MANET (2)

- Le MANET sono sistemi altamente dinamici, a causa
  - del duplice ruolo ricoperto da ogni host
  - del continuo cambiamento nella topologia della rete,
- Due aspetti della dinamica:
  - dinamica della rete: cambiamento della posizione degli host
  - dinamica del comportamento computazionale di ogni host

Introduzione a MANET (3)

- Le MANET sono applicate per permettere la comunicazione tra
  - squadre di soccorso nel caso di disastri
  - navi durante traversate oceaniche
  - robot
  - sistemi spaziali
  - ...

Introduzione a MANET (4)

- Problemi
  - definizione di protocolli di routing specifici per questo tipo di reti
  - studio delle prestazioni
  - necessità di sincronizzazione
  - analisi della concorrenza
  - ...

Our research

The problem

- There exist several environments for simulating MANET
- Most of them
  - are event-driven simulators, where components synchronization is imposed through an external clock
  - do not allow to formally describe the system, so studying interesting computational properties is harder

Purpose

- Building an environment
  - in which synchronization is established by the internal behaviour of the *agents* in the *mobile system*
  - which allows formally modelling MANET
    - Petri Net
    - ASM

DEMONE
moDEling MObile NEtworks

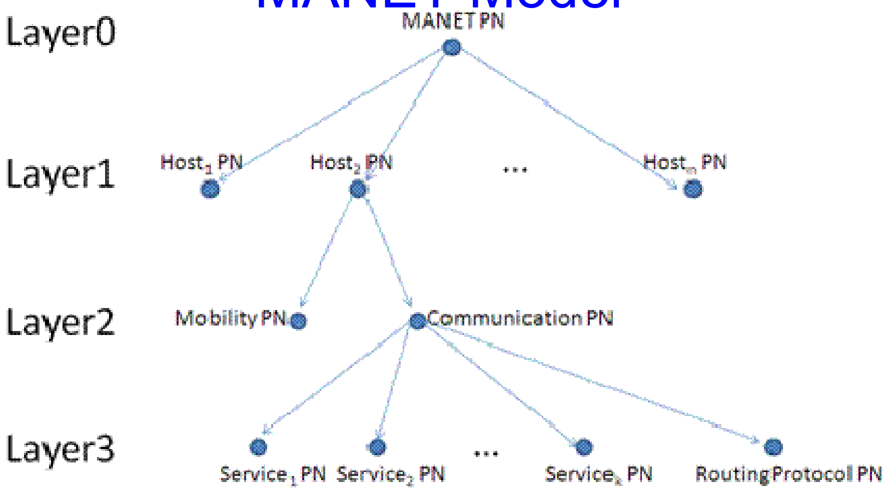
The Approach

- Modelling the MANET means describing two different abstraction levels
  - the mobile network level, i.e., the set of communicating agents, their movement and the logical links among them
  - the mobile system level, i.e., the formal description of each communicating agent
- Formal Model:
  - Colored Nested Petri Nets (current release)
  - Abstract State Machine (work in progress)
  - ... (future)

Petri Nets

- PNs model the behavior of each communicating agent
  - each communicating agent is a "system"
- Places are states of the system
  - characterized by specific values of state variables
- Transitions are associated to computational activities, which drive the evolution of the system

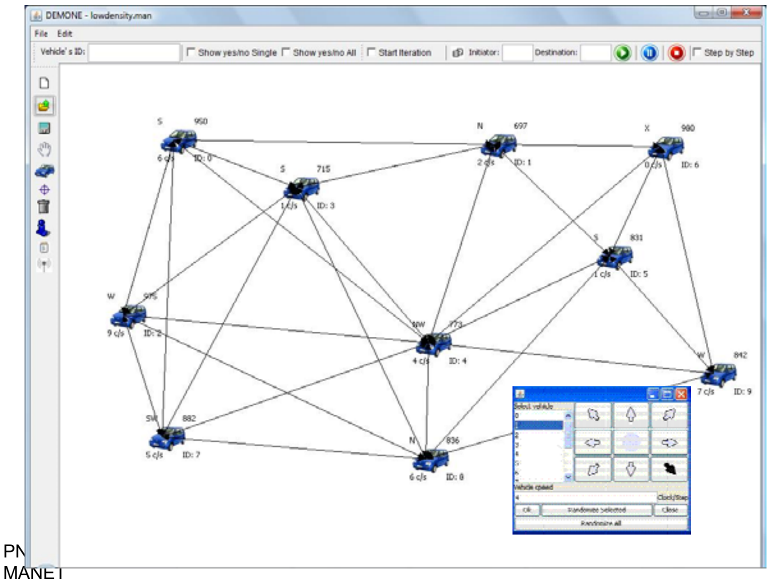
The Hierarchical Structure of MANET Model



Architecture

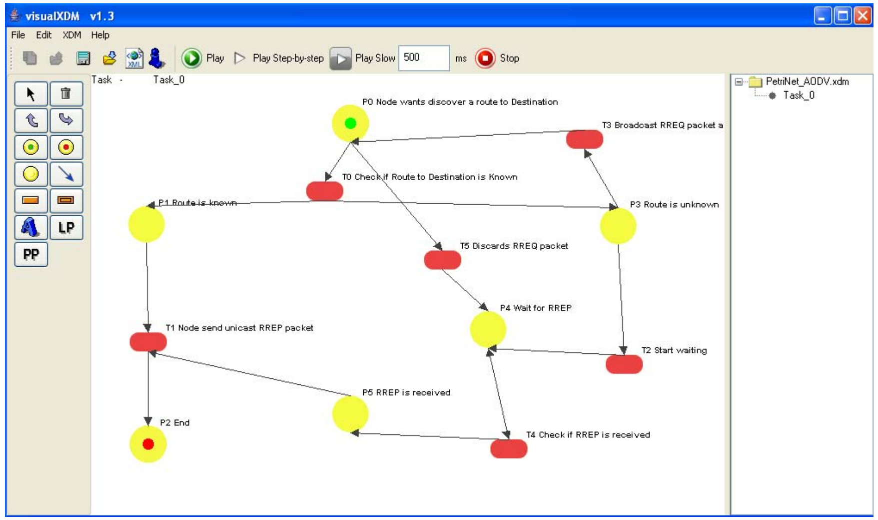
- It includes three main logical components
  - Mobile Network editor: for configuring the MANET (number and features of communicating agents)
  - Visual XDM (conteXt-sensitive Dialog Model): editor for the PN, for modeling the behavior of hosts
  - Mobile System Simulator: for simulating the entire system network and executing all PNs

MANET Editor

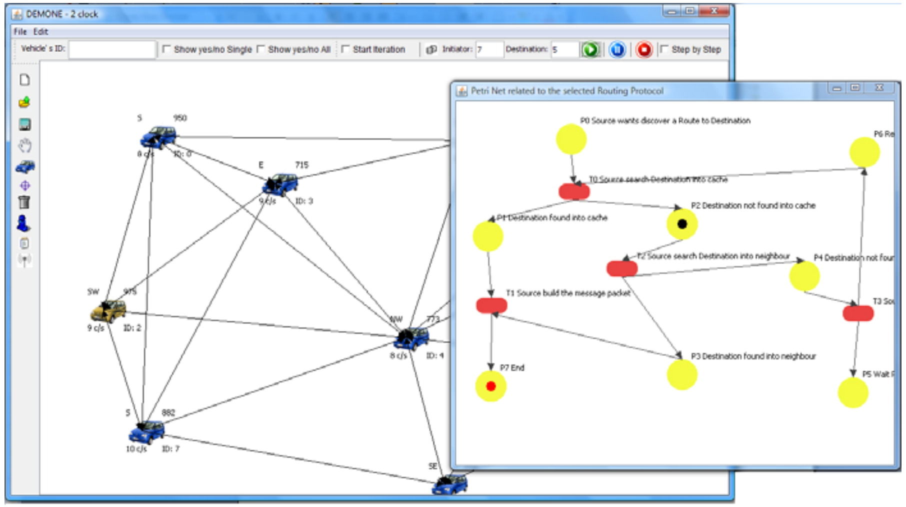


PN Editor: Visual XDM

- Specify computational behaviour of communicating agents
- Implicitly defines mobile system clock



MANET Simulation

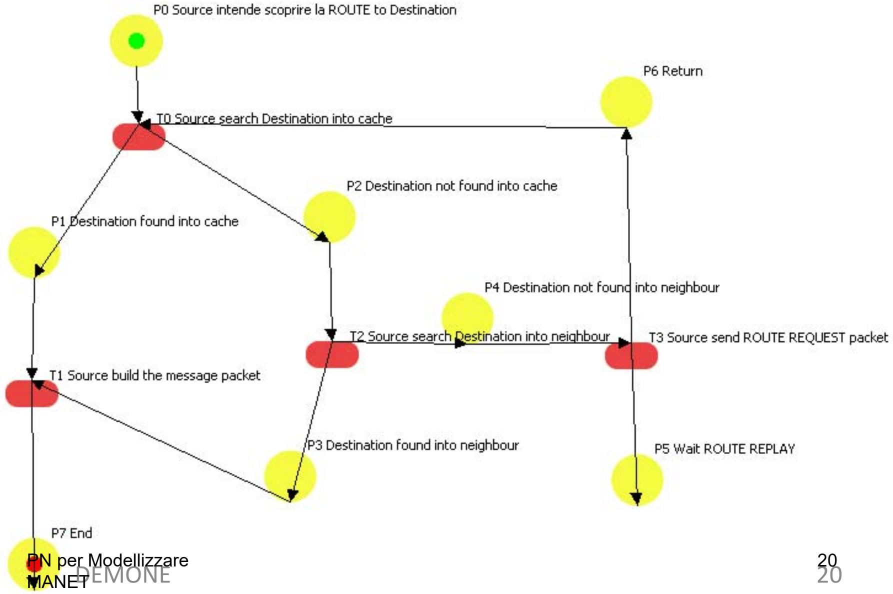


Two Routing Protocols

Dynamic Source Routing

- Initiator wants communicate with Destination
- If (Dest is a neighbour of Init) OR (a route to Dest is in Init's cache)
  - Communication can start
  - End algorithm
- Init broadcasts RREQ pck to neighbours
- Algorithm reiterated until route is found
  - RREP pck is sent back to Init

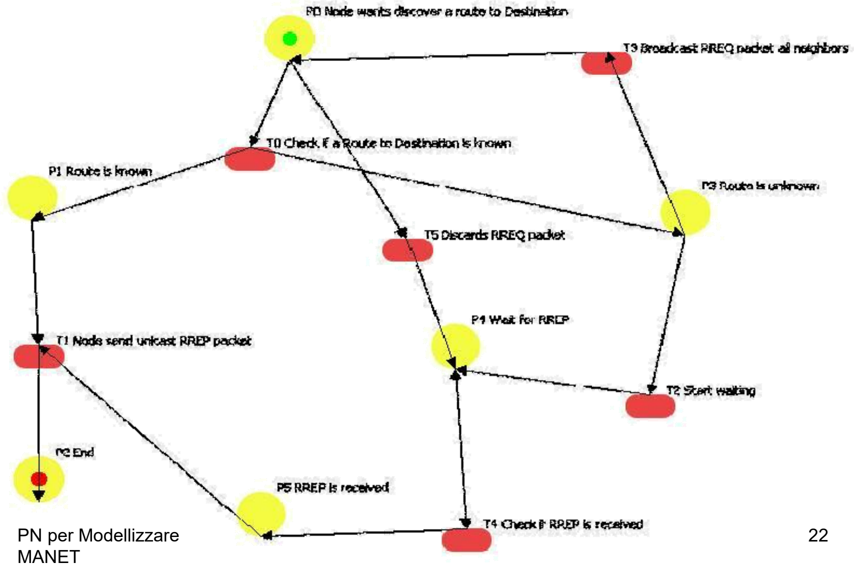
Rete di Petri DSR



Ad-hoc On demand Distance Vector - AODV

- If a route to Dest is not in Init's cache AND Dest is not a neighbour of Init
  - RREQ pck is broadcasted to neighbours
  - If a node receiving RREQ is not Dest, neither knows a route to Dest, it
    - updates its info about route to Init
    - updates RREQ with its ID
    - broadcasts the updated RREQ
  - Else it
    - unicasts a RREP pck back to Init

Rete di Petri AODV



Validation of DEMONE

The experimentation

- Purpose: Validating DEMONE as a proper tool for simulating MANET behavior
- Method: Simulating the behavior of two popular routing protocols and comparing the results obtained by DEMONE to findings in literature
  - 1500 simulations of Dynamic Source Routing (DSR) protocol
  - 1500 simulations of Ad-hoc On-demand Distance Vector (AODV) protocol

Experimental Setting

- 3 differently populated mobile networks
  - Low density: 10 hosts
  - Medium density: 20 hosts
  - High density: 30 hosts
- For each host:
  - Transmission range randomly defined at the beginning, and constant for the entire simulation
  - Speed and direction randomly defined at the beginning and randomly re-defined at each clock

Collected Data (1)

- For each protocol, 500 runs for each density
  - Total: 3000 simulations
  - In each run Init and Dest are randomly defined
- Time spent for discovering route to Dest
  - Chronological time: measured in milliseconds
  - Simulation time: measured in number of clock cycles – each PN execution is a clock cycle

Collected Data (2)

- Effectiveness: rate of success in route discovering, measured as the ratio of the total number of successful communication to the total number of trials

Collected Data (3)

- Efficiency of each protocol
  - Path optimality: (length of shortest path) / (length of actual path, discovered by the protocol)
  - Routing overhead for the network: (total number of RREQ and RREP) / (theoretical minimum number of packets required for discovery)
  - Routing overhead for each host: (number of times each host executes computational activities related to route discovery) / (network size)

Research Questions

1. For each metric M_i, except of success rate
   - H_0: There is not statistically significant difference between M_i values for DSR and AODV
   - H_1: There is a statistically significant difference between M_i values for DSR and AODV
2. Rate of success is simply compared in the two protocols
3. Is simulation time able to measure time as well as chronological time?
   - Correlation between the two time metrics in both protocols

Results (1)

- Is there statistical difference between M_i values for DSR and AODV?

Metric	10 hosts	20 hosts	30 hosts
Chronological Time	YES (0,0003) (greater for AODV)	YES (0,0166) (greater for AODV)	YES (0,0119) (greater for AODV)
Simulation time	YES (0,0000) (greater for AODV)	YES (0,0000) (greater for AODV)	YES (0,0000) (greater for AODV)
Path optimality	NO (0,1580)	YES (0,0001) (greater for AODV)	YES (0,0004) (greater for AODV)
Routing overhead (network)	YES (0,0000) (greater for AODV)	YES (0,0000) (greater for AODV)	YES (0,0000) (greater for AODV)
Routing overhead (host)	NO (0,9970)	YES (0,0395) (greater for AODV)	NO (0,9117)

Results (2)

- Effectiveness of the protocols

Protocol	10 hosts	20 hosts	30 hosts
DSR	0,7940	0,5880	0,5800
AODV	0,9800	0,8960	0,8100

Results (3)

- Is there statistical correlation between chronological time and simulation time?

Network Size	DSR	AODV
10 hosts	0,80	0,70
20 hosts	0,77	0,65
30 hosts	0,77	0,59

Analysis of Properties

Reachability

- All markings are always reachable
  - all computational activities specified in the model can be executed
  - conditions exist for executing all the components of the algorithms implementing the routing protocols

Boundedness (1)

- If some tokens represent the number of communications currently managed by the MANET, boundedness specifies the maximum number of communications the system is able to process

Boundedness(2)

- PN concerning hosts acting as router is unbound
  - each host can serve as router for indefinite number of communications
- PN concerning hosts acting as end points are 1-bound
  - Each host can start only 1 communication

Liveness

- PNs are live
  - each transition in all PNs is contained in at least a path connecting the initial marking to other markings

Conservativeness

- The PNs are not conservative
  - Tokens are created/removed depending on the specific activities
  - If tokens represent data packets received and re-sent by intermediate host, then conservativeness can be used for verifying no packet is lost during communication sessions

Reversibility

- The PNs are not reversible
  - In case of failure the control is taken by a specific module, for recovering purposes

Conclusions

Findings (1)

- In most cases the two protocols present different behavior
  - AODV is more effective, but it consumes more resources
  - This is confirmed by literature
- The empirical study validates the capability of DEMONE to simulate MANET
  - but DEMONE also allows formal modeling

Findings (2)

- Trends of Simulation time and Chronological time are analogous
- The Simulation time, established by internal behavior is a good indicator of Chronological time
  - even if they cannot be considered in the same way
  - results are encouraging and more analysis will be executed

DEMONE

- Imposes a new view on the synchronization of the system
- Allows
  - formal modelling of MANET, in order to analyse computational behaviour of communicating agents and network
  - simulation of MANET: preliminary results are analogous to results known in literature and obtained with other tools

Current /Future Work

- Simulations with larger network size (50 – 100 hosts)
- Implementation of other models
  - Abstract State Machine
- Analysis of more properties
  - Completeness: is EP reachable from SP?
  - Complexity: max number of path for reaching EP from SP