

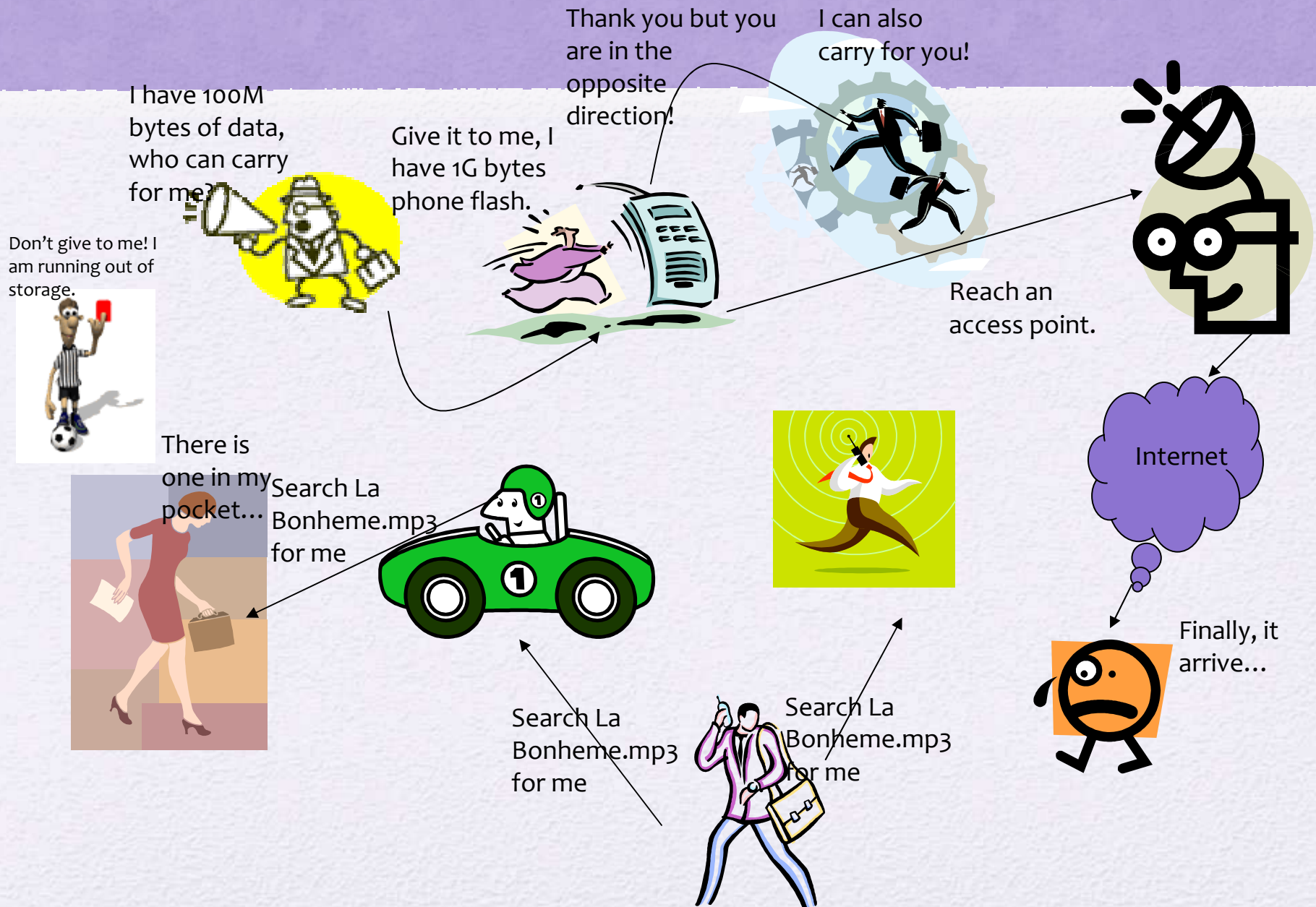
Changing the paradigm in forwarding : How transform daemons to angels?



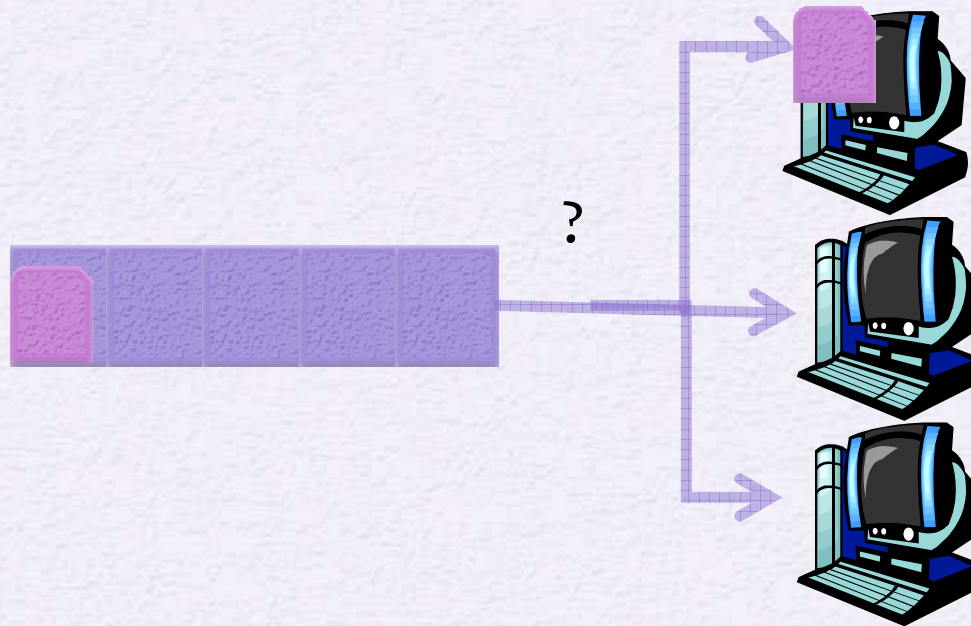
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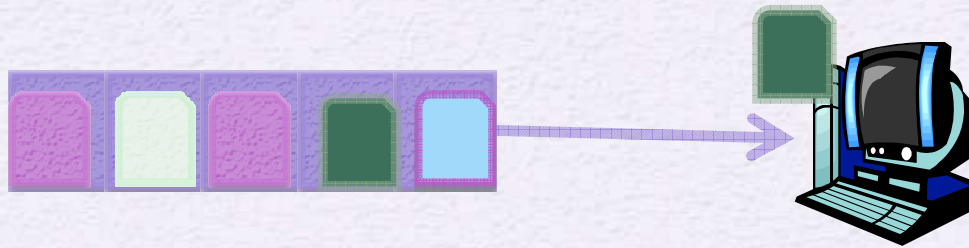
Nowadays ...



Classical forwarding

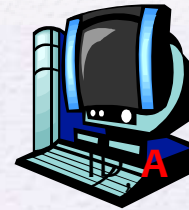


DTN, pocket networks forwarding



?

Why to forward ?



- Let's define for each packet a set of attributes A_i
 - Destination address $D(P_i)$
 - Some Attributes are extracted from packet, some are coming from local context
- Let's define a utility function $U(A_i, D(P_i), ID, \mathbf{A})$
 - The utility of forwarding message i destined to $D(P_i)$ to node ID with context $\mathbf{A}$
 - The utility function capture the selfishness of the node
- Forwarding scheme :
 - Calculate for each packet in buffer its utility
 - Forward the largest utility

Utility functions

- Classical routing : Assign the utility function 1 if the node ID is on the path to destination $D(P_i)$ null otherwise
- *PROPHET*: The delivery likelihood is the utility
- Self Limiting Epidemic forwarding: The utility is scaled down everytime a packet is received or forwarded.
- Community or content networking :Give a higher utility to some contents or community.
- What if the utility doesn't depend on destination adress ?
 - Results in epidemic forwarding
- Might construct utility function changing over time and adapting to information increase
 - Spray and focus
 - Move from opportunistic to infrastructure mode

Random utility

- Utility is hard to assess, we might do mistakes
 - $U(A_i, D(P_i), ID, \mathbf{A}) = \hat{U}(A_i, D(P_i), ID, \mathbf{A}) + \text{noise}$
- Knowing a set of estimated utility $\{\hat{U}_i\}$ what is the probability that choice j is the real best choice ?

$$\Pr\{j \text{ is the best choice}\} = \frac{e^{\mu \hat{U}_j}}{\sum_i e^{\mu \hat{U}_i}}$$

- Noise should follow a Gumble distribution
- Forwarding scheme
 - Choose packets to forward following above distribution

Forwarding for challenging environments

- Very mobile, very dynamic environments
- No prediction on future encounters
 - No bias in the utility function based on destination address
 - Results in epidemic forwarding
- Flooding is evil !
 - Generate lots of redundancy
 - Reduce injection rate
 - Going from point to point capacity bound to broadcast capacity bounds
- But Flooding is great
 - Shortest path
 - No need for global information
 - Will work whenever communication is possible.
- Is it possible to make flooding less evil ?
 - Controlling the redundancy
 - Controlling the scope

Controlling the redundancy

- Let's forward in place of a packet a linear combination of packets : Network coding !
 - Reduce the redundancy
- Use feedback to indicate received packets
 - How to do this feedback ?

Issues

- Generation problem
 - How to ensure that the number of variables do not grow faster than the number of equation:
congestion !
 - Congestion control needed
 - How to ?
- Incentives/punishment?
 - How to deal with selfish nodes
 - Node that are just sending their packets and not forwarding others

Collaboration Incentives

- Nodes are selfish
 - Send as most a possible their own messages
 - Just forward message when there is a benefit
- They are pragmatic and rational
- They have a limited patience and resources

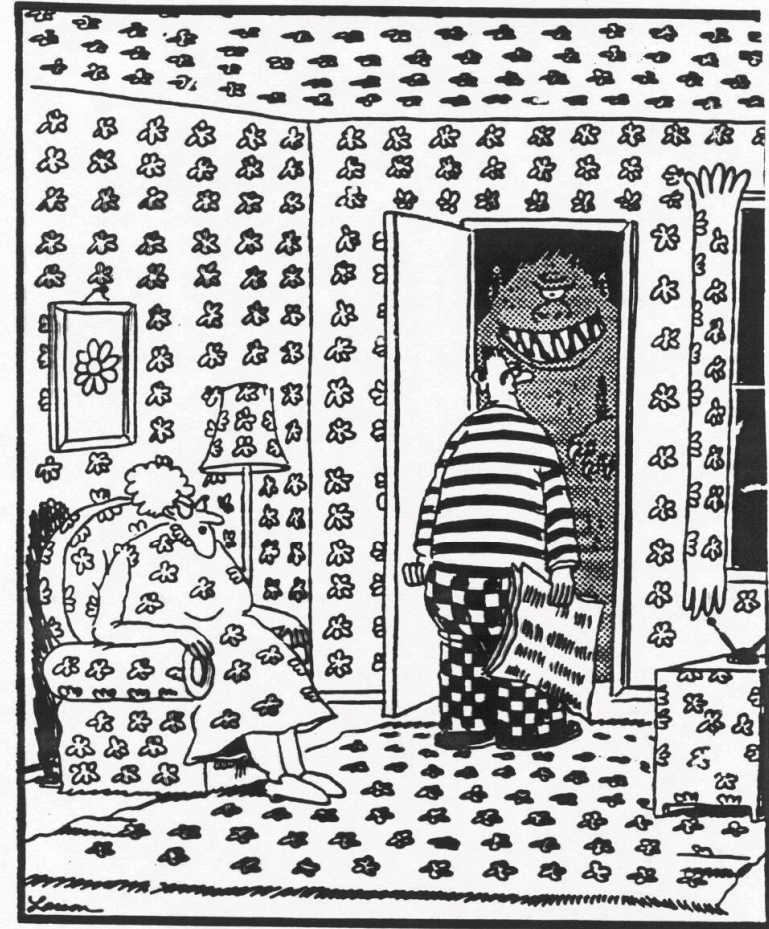


Limited resources

- A node do not want to use more than K buffer space for forwarding
 - Out of these can k be undecoded and $K-k$ are decoded
- A node piggyback
 - its capacity
 - List of packet decoded
 - List of packet received
 - List of packet non decoded is derived from the two above
- Neighbor should take care of this capacity in forwarding
 - A neighbor have no incentive to go higher than the advertised capacity
 - A node have no incentive to lie about its capacity

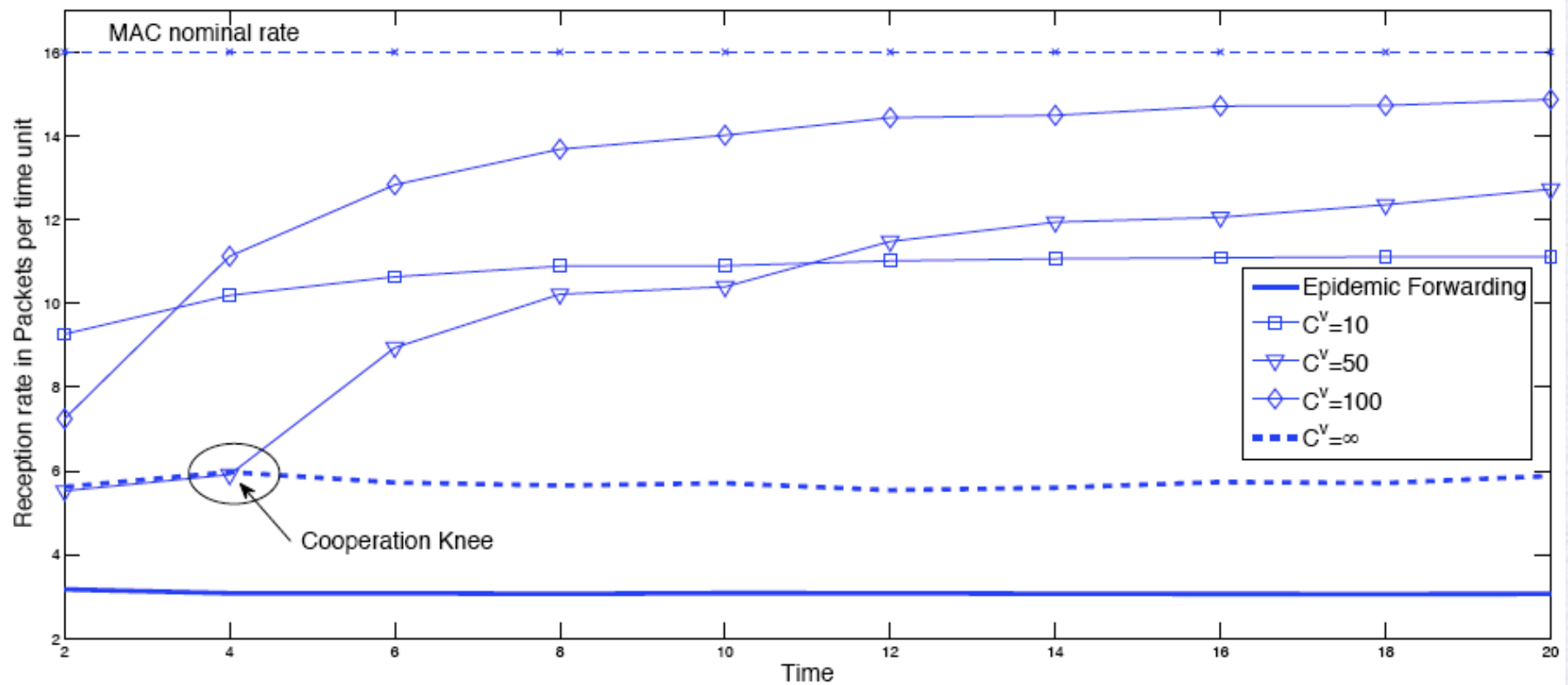
Enforcing collaboration

- Finite buffer space for forwarding
 - Informs other about your capacity
 - Neighbor take care of your constraint for their own sake
 - Mixing packets help neighbors in solving their equations and freeing space for sending your packets
- Results in a Pareto-Optimal cooperation mechanism
- **Being social becomes helpful**
 - Entangling your transmission with others is a way of enforcing collaboration
 - Totally antagonistic with QoS
- **Cooperation by punishment not by incentives**

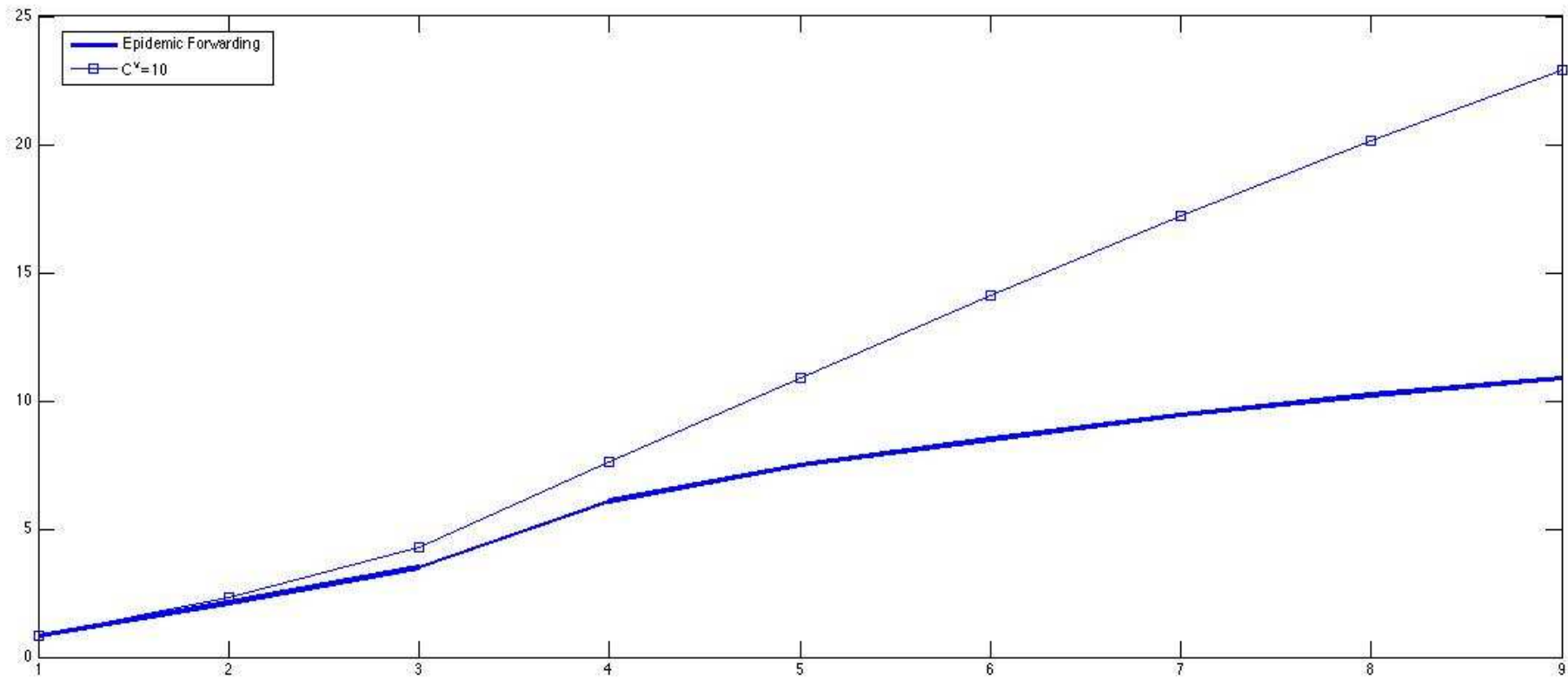


When the monster came, Lola, like the peppered moth and the arctic hare, remained motionless and undetected. Harold, of course, was immediately devoured.

Performances



Infocom 2006 scenario



Infocom Scenario

