Publish/Subscribe Systems on Node and Link Error-Prone Mobile Environments

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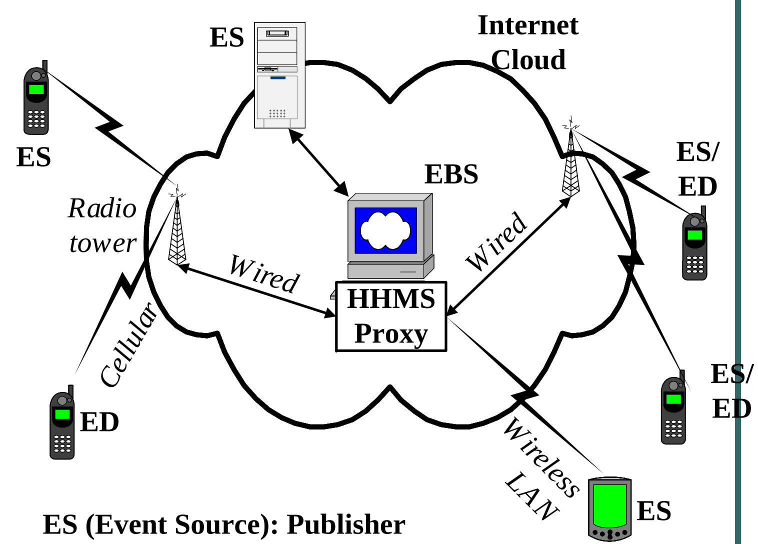
http://grids.ucs.indiana.edu/ptliupages/hhms/pub-sub.html

Introduction

Introduction

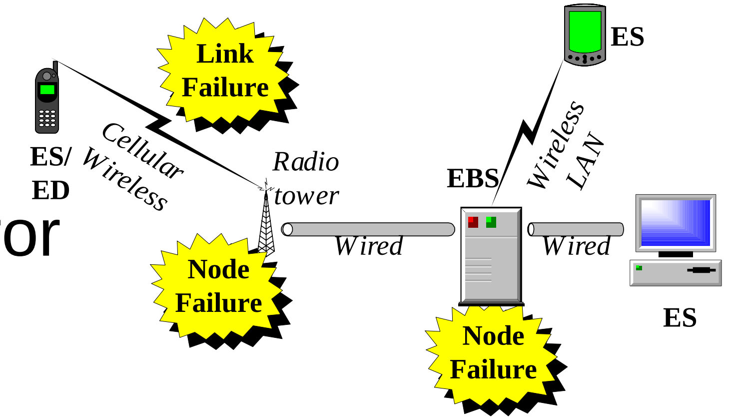
- Advantages of publish/subscribe systems in mobile computing
  - Intermittent and high-latency
  - Decoupling publisher and subscriber
  - Appropriate in mobile and ubiquitous environments
  - *Data dissemination services*
  - *Information sharing*
  - *Service discovery*



Motivations

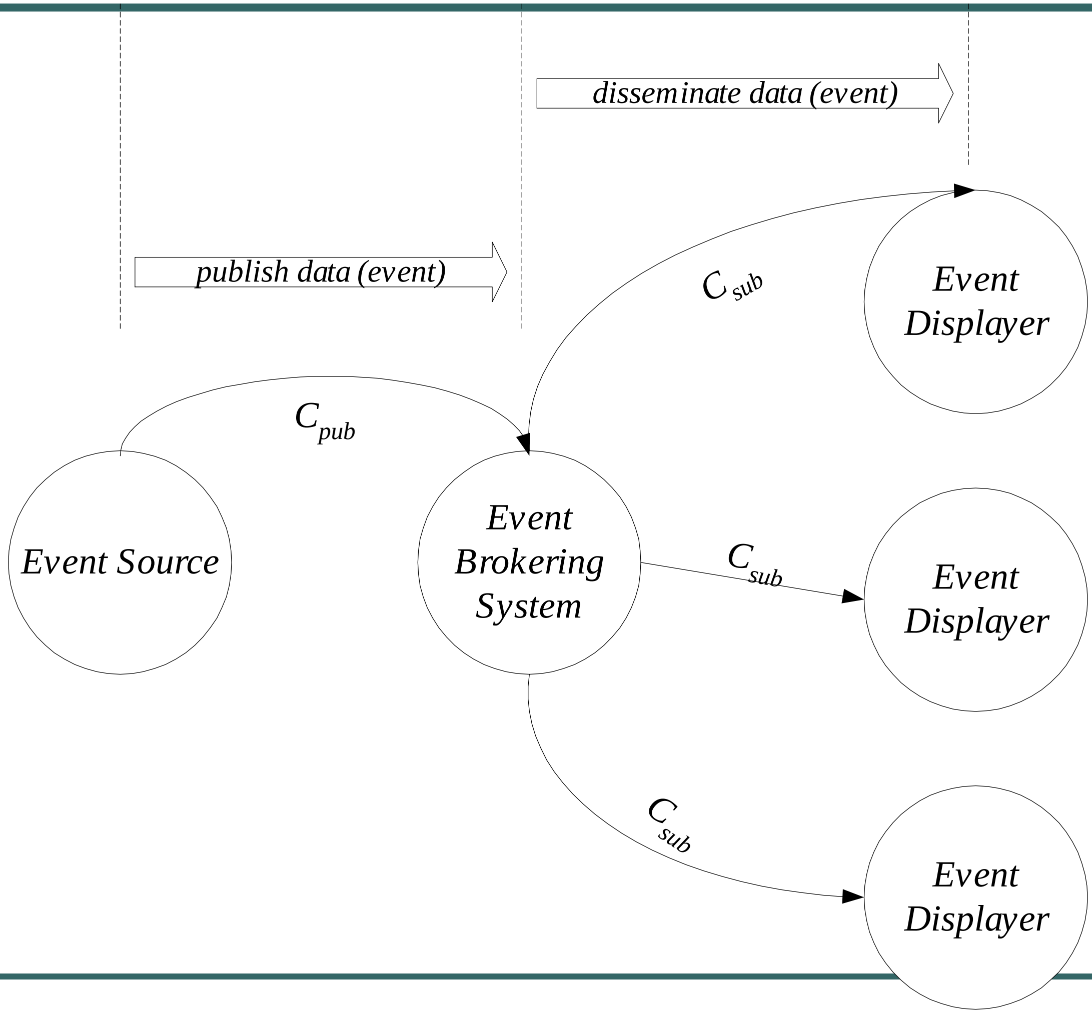
- Mobile environments are error prone
  - Wireless link disconnection, Power Exhaustion
- In the presentation, we analyze the influence of error
  - Mobile link and node
  - Comparison pub/sub to client-server

    and polling models



Cost Model

System model



System parameters

α (publish rate)
β (request rate or process
(reference access) rate)
$\mathbf{c_{ps}(\alpha)}$ (publish/subscribe cost per event)
$\mathbf{c_{rr}(\beta)}$ (cost per request and reply)
$\mathbf{c_{poll}(\alpha,T)}$ (cost of periodic publish or polling)
s(n) (effect of sharing among n subscribers)
$\mathbf{t_{ps}}$ (time delay for publish/subscribe)
$\mathbf{t_{rr}}$ (time delay for request and reply)
λ, λ_s, λ_c (failure rate of
communication link, server, and client)
μ, μ_s, μ_c (recovery rate of
communication link, server, and client)

Cost Analysis

Considerations and Assumptions

- Analyzing four models:
  Disconnection (failure) and reconnection (recovery) of link and node failure
  1. Publish/subscribe
  2. Event (broker) based request/reply
  3. Conventional request/reply
  4. Periodic polling

- Cost metric → time delay to transfer message and additional time required due to failure of communication links and nodes of servers and clients

- *Persistent files*
  for events are sharable among servers. When a server fails, the another server can take over the role and publish/server model can continue its transactions.
- *Durable database*
  saves events log and provides clients events history after clients recovers from failures.

Characteristics on Failures

Models	*Types*	*Link failures*	*Server failures*	*Client failures*
publish /subscribe	*publish /subscribe*	*Wait until link reconnection, transaction is preserved*	*Server is replicated and transaction can be continued with sharable persistent file*	*After recovery, client can access events occurred during failure using events log on durable database*
Event message based request/reply	*request /reply*	*Wait until link reconnection, transaction is preserved*	*Server is replicated and transaction can be continued with sharable persistent file*	*After recovery, client can access events occurred during failure using events log on durable database*
request/reply (RPC)	*request /reply*	*Wait until link reconnection, transaction needs to restart*	*Transaction needs to restart after recovery*	*Lost event or data during client failure*
periodic polling	*any*	*Wait until link reconnection*	*Depends on system*	*Depends on system*

Cost Analysis I
Publish/subscribe model

- Cost of message transfer = $(c_{pub} + n\, s(n) c_{sub})$, plus delay time from link and/or node failure

Probability of subscriber access event before reconnection

- Failure of communication link
  1. Probability of disconnection during transaction $(\mu/(\lambda+\mu)(1-\ \varepsilon^{-(t_{pub}+t_{sub})\lambda})$
  2. Probability of communication link disconnection $(\lambda/(\lambda+\mu))$

$t_{pub} + t_{sub} + \{\mu/(\lambda+\mu)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda}) + \lambda/(\lambda+\mu)\}\{\beta/(\mu+\beta)\}(1/\mu)$.

Probability of disconnection

Aver. Delay time

- Failure of server
  - Assumption: 1) Another server takes over the failed server, 2) ignores the cost required for transaction from failed server to backup server

$$t_{ps} = t_{pub} + t_{sub}$$

- Failure of client
  - Assumption: Durable data → Client get any information after recovery (n_{log})
  - Probability of i event occurred between failure and recovery → $\left(\frac{\alpha}{\alpha+\mu_c}\right)^i \frac{\mu_c}{\alpha+\mu_c}$
  - If , i - n_{log} events are lost due to exceeding limitation of capacity for event log
    Thus, aver. number of lost events per client failure →

$$\sum_{i=n_{log}+1}^{\infty}\left(\frac{\alpha}{\alpha+\mu_c}\right)^i \frac{\mu_c}{\alpha+\mu_c}(i-n_{log}) = \left(\frac{\alpha}{\alpha+\mu_c}\right)^{n_{log}} \frac{\alpha}{\mu_c}$$

Cost Analysis II
Event (broker)-based request/reply

- Cost of message transfer = c_{rr} , plus delay time from link and/or node failure

- Failure of communication link
  1. Probability of disconnection during transaction (μ/(λ+μ)(1 $\varepsilon^{-t_{rr}\lambda}$)
  2. Probability of communication link disconnection (λ/(λ+μ))

t_{rr} + {μ /(λ+μ)(1 $\varepsilon^{-t_{rr}\lambda}$)+λ/(λ+μ)}(1/μ)

Probability of disconnection

Aver. Delay time

- Failure of server
  - Assumption: 1) Another server takes over the failed server, 2) ignores the cost required for transaction from failed server to backup server

t_{rr}

- Failure of client
  - Assumption: Durable data → Client gets any information after recovery
  - Probability of *i* event occurred between failure and recovery

→ $$\left(\frac{\alpha}{\alpha+\mu_c}\right)^i \frac{\mu_c}{\alpha+\mu_c}$$

Cost Analysis III
RPC Based Request/Reply model

- Assumption
  - No-persistent, No-durable
  - Additional overhead → 'useless computation' (re-generating request/reply, which is < t_{rr} + t_{proc})
  - 'Server recovery overhead' is ignored like other models.

- Failure of communication link
  1. Link doesn't fail
     probability is 1 - μ/(λ+μ)(1- $\varepsilon^{-(t_{pub}+t_{sub})\lambda}$) - λ/(λ+μ) → t_{rr}
  2. Link failed
     probability is λ/(λ+μ) → recovery cost 1/μ + restart c_{rr}
  3. Link failed during transaction
     probability is μ/(λ+μ)(1- $\varepsilon^{-(t_{pub}+t_{sub})\lambda}$)

Useless Computation: E(t_{rr}+t_{proc},λ)

The function E denotes amount of time, length x, and failure ratio of λ

$$E(t_{rr}+t_{proc},\lambda) = \int_0^x t\frac{\lambda\varepsilon^{-\lambda t}}{1-\varepsilon^{-\lambda t}}dt = \lambda^{-1} - \frac{x\varepsilon^{-\lambda x}}{1-\varepsilon^{-\lambda x}}$$

c_{rr} = [1 - { μ/(λ+μ) (1- $\varepsilon^{-(t_{pub}+t_{sub})\lambda}$) + λ/(λ+μ)}] t_{rr}
+ μ/(λ+μ) (1- $\varepsilon^{-(t_{pub}+t_{sub})\lambda}$) { E(t_{rr}+t_{proc},λ) + 1/μ + c_{rr}} + λ/(λ+μ){(1/μ)+ c_{rr}}

➔ c_{rr} = [[1 - {μ /(λ+μ) (1- $\varepsilon^{-(t_{pub}+t_{sub})\lambda}$) + λ/(λ+μ)}] t_{rr}
+ μ/(λ+μ) (1- $\varepsilon^{-(t_{pub}+t_{sub})\lambda}$) {E(t_{rr}+t_{proc},λ) + 1/μ} + λ/(λ+μ)(1/μ)]
/ [1 - { μ/(λ+μ) (1- $\varepsilon^{-(t_{pub}+t_{sub})\lambda}$) + λ/(λ+μ)]

Cost Analysis III
RPC Based Request/Reply model

- Failure of server
  1. Server doesn't fail
     : *probability is* $1 - \mu_s/(\lambda_s+\mu_s)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda s}) - \lambda_s/(\lambda_s+\mu_s) \rightarrow t_{rr}$
  2. Server failed
     : *probability is* $\lambda_s/(\lambda_s+\mu_s) \rightarrow$ recovery cost $1/\mu_s$ + restart c_{rr}
  3. Server failed during transaction
     : *probability is* $\mu_s/(\lambda_s+\mu_s)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda s})$

$$c_{rr} = [1 - \{ \mu_s/(\lambda_s+\mu_s)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda s}) + \lambda_s/(\lambda_s+\mu_s)\}]\, t_{rr}$$
$$+ \mu_s/(\lambda_s+\mu_s)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda s}) \{ E(t_{rr}+t_{proc},\lambda_s) + 1/\mu_s + c_{rr}\} + \lambda_s/(\lambda_s+\mu_s)\{(1/\mu_s)+c_{rr}\}$$

$$\rightarrow c_{rr} = [\, [1 - \{\mu_s/(\lambda_s+\mu_s)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda s}) + \lambda_s/(\lambda_s+\mu_s)\}]\, t_{rr}$$
$$+ \mu_s/(\lambda_s+\mu_s)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda s}) \{E(t_{rr}+t_{proc},\lambda_s) + 1/\mu_s\} + \lambda_s/(\lambda_s+\mu_s)(1/\mu_s)]$$
$$/\, [\, 1 - \{ \mu_s/(\lambda_s+\mu_s)(1- \varepsilon^{-(t_{pub}+t_{sub})\lambda s}) + \lambda_s/(\lambda_s+\mu_s)]$$

- Failure of client
  - Assumption
    current data only and no-logging data
  - Only the data occurred during the failure will be lost.

Useless Computation: $E(t_{rr}+t_{proc},\lambda_S)$

The function E denotes amount of time, length x, and failure ratio of λ

$$E(t_{rr}+t_{proc},\lambda) = \int_0^x t \frac{\lambda \varepsilon^{-\lambda t}}{1-\varepsilon^{-\lambda t}} dt = \lambda^{-1} - \frac{x\varepsilon^{-\lambda x}}{1-\varepsilon^{-\lambda x}}$$

Cost Analysis IV
Periodic (Polling) model

- Assumption
  - Polling is delayed until communication link is recovered.
  - the persistent file and durable database
- Link was disconnected or is disconnected during the transaction
  - Time delay =

    $t_{poll}(\alpha,T) + \{\mu/(\lambda+\mu)\ \varepsilon^{-t_{poll}(\alpha,T)\lambda} + \lambda/(\lambda+\mu)\}(1/\mu)$
  - Conceptual cost =

    $c_{poll}(\alpha,T) + [1 - \{\mu/(\lambda+\mu)\ \varepsilon^{-t_{poll}(\alpha,T)\lambda} + \lambda/(\lambda+\mu)\}]\ c_{delay}(\alpha,T)$

    $+ \{\mu/(\lambda+\mu)\ \varepsilon^{-t_{poll}(\alpha,T)\lambda} + \lambda/(\lambda+\mu)\}\ c_{delay}(\alpha,T+1/\mu)$

Probability of disconnection

- Failure of communication link

$$t_{rr} + \{\mu/(\lambda+\mu)(1-\varepsilon^{-t_{rr}\lambda})+\lambda/(\lambda+\mu)\}(1/\mu)$$

- Failure of server

$$t_{rr}$$

- Failure of client

$$\left(\frac{\alpha}{\alpha+\mu_c}\right)^i \frac{\mu_c}{\alpha+\mu_c}$$

Performance Comparisons

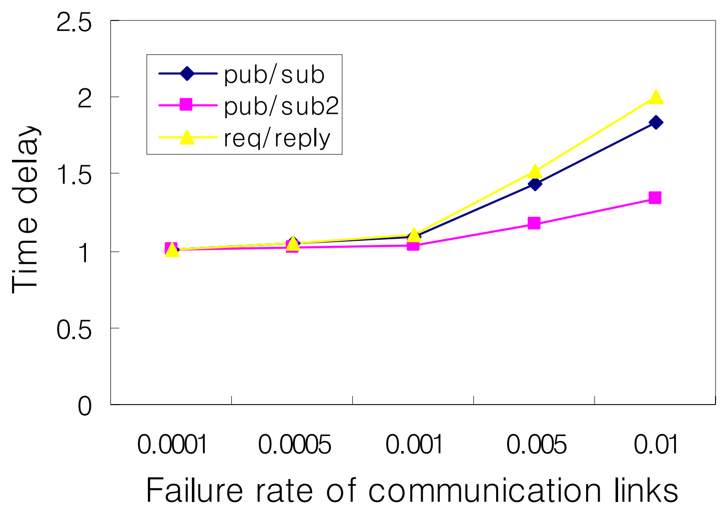
Performance Comparisons by parametric analysis

- Publish/subscribe system requires less communication delay.
- Assumption

Models	Delays
Publish/subscribe system & Event-based request/reply	Only need communication delay ← Backup server
RPC-based request/reply system	Need additional time delay and lost communication ← Server failure

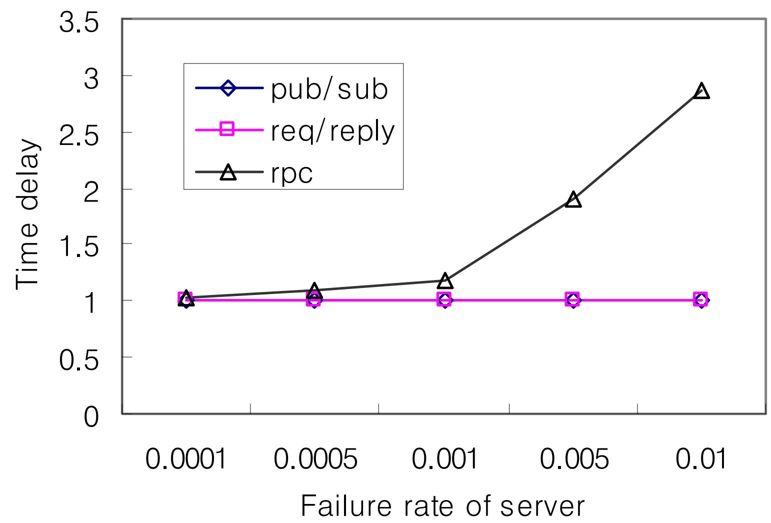
System parameters	
Param.	**Values**
α, β	0.5
c_{ps}, c_{rr}	2
c_{pub} , c_{sub}	1
$c_{poll}(\alpha, T)$	1 or α T
$c_{delay}(\alpha,T)$	0, T, or α T
s(n)	1/n - 1
λ , λ_s, λ_c	0.0001 – 0.5
μ, μ_s	0.1
μ_c	0.05 - 0.1
t_{ps} , t_{rr}	1
t_{proc}	1 or 5
$t_{poll}(\alpha, T)$	1, T, or α T

Performance comparisons II



Time delay per transaction

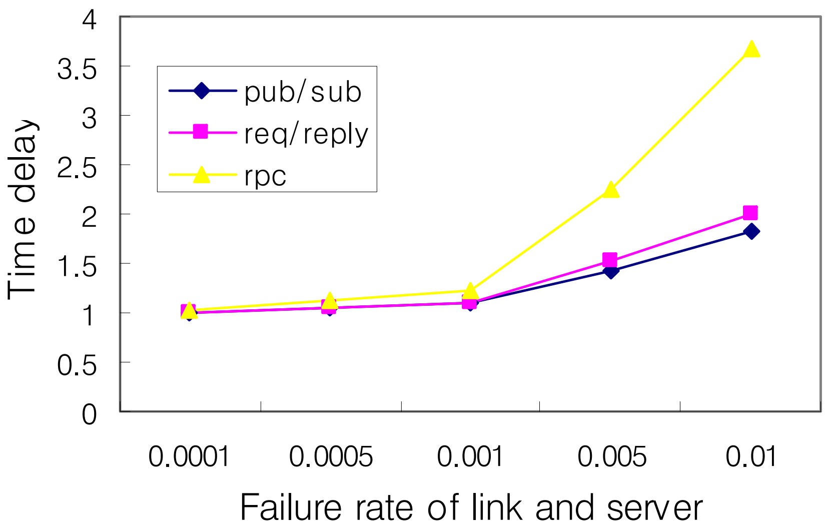
(α=0.5, s(n)=1, t_{ps}=1, t_{rr}=1, μ=0.1, and β=0.5 for pub/sub and req/reply and β=0.2 for pub/sub2)

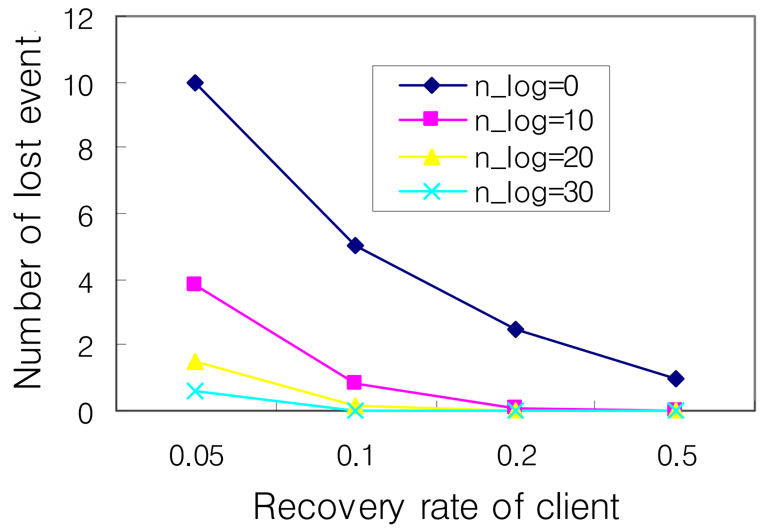


Time delay per transaction

(α=0.5, t_{ps}=1, t_{rr}=1, β=0.5, and μs=0.1)

Performance comparisons III





Time delay per transaction

(α=0.5, t_{ps}=1, t_{rr}=1, t_{poll}=1, β=0.5, μ=0.1, μs=0.1)

Number of lost events per client failure by varying recovery rate of client

(effectiveness of durable database which logs events)

Experimental Setup

- Using NaradaBrokering as message brokering system -- MOM (Message Oriented Middleware) **for publish/subscribe**
- Using HHMS (Handheld Message Service) as primary application level transport protocol **for publish/subscribe** between mobile device and conventional wired environment
- Conventional RPC code using J2SE and J2ME MIDP 2.0 **for request/reply**
- Experimental Specifications
  - Treo600:

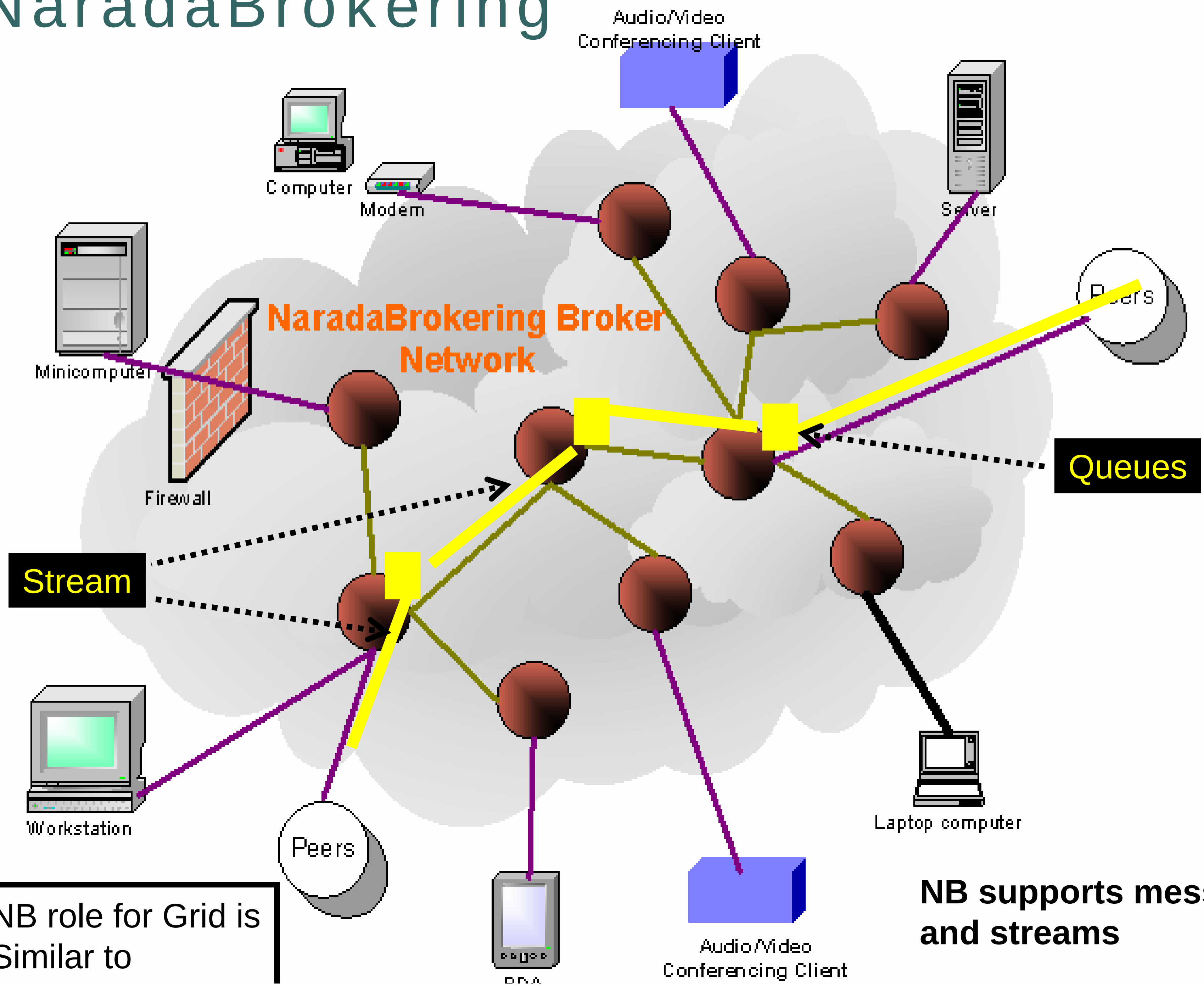
    PalmOS 5.2 144MHz ARM, 32MB, Sprint PCS Service (<14.4kbps)
  - HHMS Gateway and NaradaBrokering:

    Linux 7.3, Pentium III 1GHz, 512MB
  - Timer: Linux native timer by JNI

NaradaBrokering

- Developed by Community Grids Laboratory of Indiana University
- Message Oriented Middleware (MOM)
  - Multiple protocol transport support: In publish-subscribe Paradigm with different Protocols on each link
  - Subscription Formats
  - Reliable delivery
  - Ordered delivery
  - Recovery and Replay
  - Security
  - Message Payload options
  - Messaging Related Compliance
  - Grid Feature Support
  - Web Services supported

NaradaBrokering

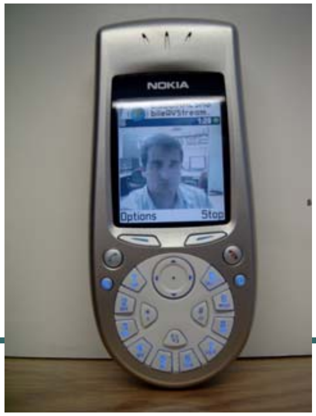


NB role for Grid is Similar to

NB supports messages and streams

Handheld Messaging Service

- Light-weight publish/subscribe message service framework for mobile devices
- Optimized application level transport protocol using byte message format
- Provide core-subset of JMS API



Experiment results

- Simple server → sending 10 bytes messages
- Echo client → return the message back
- Round Trip Time (RTT)

  ← median is chosen among 2000 iteration
- It shows matching result with our parametric analysis

$$t_{ps} = t_{rr} = 1$$

Delay time of sending message

	Wireless	*Wired*	*Total (msec.)*
RPC	*1290.7 (client – gateway)*	*39.9 (gateway – server)*	**1330.6 (t_{rr})**
Pub/Sub	*1448.4 (ED – EBS)*	*89.7 (EBS – ES)*	**1538.1 (t_{ps})**

Conclusion

Conclusion

- Advantages of publish/subscribe system in push based mobile applications.
- Problem: Error-prone mobile environments
  - Link disconnection
  - Power exhaustion
- Publish/subscribe system has improved performance and effectiveness on failure of client and server node, and disconnection of communication link.
- Our analysis shows publish/subscribe system is more durable than client/server model in mobile environments