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Active Control by a Mobile Client of Subscription Notifications in Smart Space

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Smart-M3 Platform

- Implements infrastructure of Smart Spaces for knowledge sharing by agents (M3-agent, knowledge processor, KP)
- SIB: Semantic Information Broker for maintenance of shared content
- RDF data representation model: semantic interoperability and ontology-driven programming
SmartRoom System

- Many services (composition, personalization)
  - informational, control, collaborative work, ...
- Participation of many users (user can be indoor and outdoor)
  - Many (mobile) clients running and accessing services
- Users come with own devices
  - Many mobile platforms, IoT-like device diversity

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Publish/subscribe in Smart Spaces

- Subscription process:
  - a publisher produces some informational content
  - subscriber is interested in certain content
  - a change can affect many subscribers
  - content can be changed by different publishers

- For Smart-M3:
  - subscription requires its client to establish a network connection
  - changes are controlled on the smart space side
  - the corresponding notifications are sent to the client (passive)
Delivery guarantee problem

- Subscription Problems:
  - Broker (SIB) doesn’t check delivery for already sent notifications
  - In mobile clients:
    - the subscription is affected by losses of notifications
    - fault tolerance is essentially affected due to the specifics of wireless network communication (Wi-Fi, 3G, etc.)

- Solution:
  - Active control by a mobile client itself for subscription notifications
  - Additional checks allows mitigate the effects of notification losses
Subscription Parameters at the Client Side

The tradeoff of passive and active notifications:

- Notifications arrive sequentially to the client
- $i$ is the sequence number of a notification
- $t_i$ is the time interval
- $k_i$ is the observed number of losses
- $\lambda = \lambda_i = k_i / t_i$ is the instant rate for the notification loss

$\Rightarrow$ The client is interested in minimizing $\lambda$. 
Subscription process example

$\begin{align*}
&k_{i-1} = 1 \\
&t_i = 1
\end{align*}$

Diagram:

- Client
- Broker
- KP
- Publishing

Connections:
- $A \rightarrow \text{Connection error} \rightarrow B$
- $B \rightarrow \text{Connection error} \rightarrow C$
- $C \rightarrow \text{Connection error} \rightarrow D$
- $D \rightarrow \text{Publishing}$

- $A \rightarrow \text{Check on losses} \rightarrow D$
- $D \rightarrow \text{Publishing}$
Mathematical Model

■ With active notifications, $t_i$ becomes a control variable for the client
■ Let the client have observed no losses in $t_{i-1}$, i.e., $k_{i-1} = 0$:

$$ t_i = t_{i-1} + \delta \quad (1) $$

■ Let the client have observed certain losses in $t_{i-1}$, i.e., $k_{i-1} > 0$:

$$ t_i = \alpha t_{i-1} + (1 - \alpha) \frac{t_{i-1}}{k_{i-1} + 1} \quad (2) $$

■ Combining (1) and (2) we construct the recurrent system

$$ t_i = \begin{cases} 
  t_{i-1} + \delta & \text{if } k_{i-1} = 0, \\
  1 + \alpha k_{i-1} & \text{if } k_{i-1} > 0. 
\end{cases} \quad (3) $$
Experiments: Adaptive Strategy

Behaviour of strategy for different distribution of notifications losses:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$a$</td>
<td>0</td>
<td>$k_i \in [at_i, bt_i]$ uniformly at random</td>
</tr>
<tr>
<td>$b$</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Poisson distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.05</td>
<td>$k_i P(\lambda t_i)$ for $\lambda &gt; 0$</td>
</tr>
</tbody>
</table>

Our strategy:

$$t_i = \begin{cases} 
  t_{i-1} + \delta \\
  \frac{1 + \alpha k_{i-1}}{k_{i-1} + 1} t_{i-1} 
\end{cases}$$

$\alpha = 0.5$, $\delta = 20$
## Experiments: Compared Strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adaptive strategy</strong></td>
<td>$\alpha$</td>
<td>0.5</td>
<td>$\alpha = 0.5$ trades off previous and recent observations equally. $\delta = 20$ s is equal to the interval for one loss on average.</td>
</tr>
<tr>
<td></td>
<td>$\delta$</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>Multiplicative decrease</strong></td>
<td>factor</td>
<td>0.5</td>
<td>When $k_{i-1} &gt; 0$ the check interval $t_i$ is reduced by 2. If $k_{i-1} = 0$ then set $t_i = t_0$.</td>
</tr>
<tr>
<td><strong>Random selection</strong></td>
<td>$a$</td>
<td>10</td>
<td>Random strategy when $t_i$ is selected from interval $(a, b)$ at random.</td>
</tr>
<tr>
<td></td>
<td>$b$</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td><strong>Constant check interval</strong></td>
<td></td>
<td></td>
<td>The check interval is always set $t_i = t_0$.</td>
</tr>
</tbody>
</table>

The initial value is $t_0 = 20$ s, which confirms the intuition that one loss happens on this interval on average.
### Experiments: Comparison

<table>
<thead>
<tr>
<th>Metric</th>
<th>Multiply decrease</th>
<th>Random selection</th>
<th>Constant interval</th>
<th>Adaptive strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_{\text{avg}} = \frac{1}{n} \sum_{i=1}^{n} k_i$ (min)</td>
<td>0.59</td>
<td>1.19</td>
<td>0.89</td>
<td>1.23</td>
</tr>
<tr>
<td>$t_{\text{avg}} = \frac{1}{n} \sum_{i=1}^{n} t_i$ (max)</td>
<td>14.23</td>
<td>19.87</td>
<td>20</td>
<td>28.8</td>
</tr>
<tr>
<td>$\lambda = \frac{k_{\text{avg}}}{t_{\text{avg}}}$ (min)</td>
<td>0.042</td>
<td>0.06</td>
<td>0.045</td>
<td>0.041</td>
</tr>
<tr>
<td>$\lambda_{\text{avg}} = \frac{1}{n} \sum_{i=1}^{n} \frac{k_i}{t_i}$ (min)</td>
<td>0.078</td>
<td>0.06</td>
<td>0.045</td>
<td>0.043</td>
</tr>
</tbody>
</table>
Experiments: Variation of $\delta$ in the Adaptive Strategy

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta$</td>
<td>10 20 40 60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_{\text{avg}} = \frac{1}{n} \sum_{i=1}^{n} k_i \ (\text{min})$</td>
<td>1.06 1.14 1.77 2.16</td>
</tr>
<tr>
<td>$t_{\text{avg}} = \frac{1}{n} \sum_{i=1}^{n} t_i \ (\text{max})$</td>
<td>22.01 24.76 32.6 43.86</td>
</tr>
<tr>
<td>$\lambda = \frac{k_{\text{avg}}}{t_{\text{avg}}} \ (\text{min})$</td>
<td>0.048 0.046 0.047 0.054</td>
</tr>
<tr>
<td>$\lambda_{\text{avg}} = \frac{1}{n} \sum_{i=1}^{n} \frac{k_i}{t_i} \ (\text{min})$</td>
<td>0.047 0.045 0.046 0.054</td>
</tr>
</tbody>
</table>

- Smaller values for $\delta$ leads to less losses
- Bigger values reduce the load the client shifts to the SIB
Conclusion

- Studied the problem of subscription fault tolerance
- Proposed a simple mathematical model for active control
- Start to apply the model in real settings

Thank you for attention

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