Abstract Channels as connectors for software components in group communication services

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Plan

• **Context and contribution**
• Causality and delivery modes
• Multiple delivery modes and abstract channels
• Multimodal communication
Distributed Cooperation

Software components: distributed agents or processes.

Group communication services:

• Membership
• Multicast and broadcast channels with delivery properties
Communications

• Agents exchange different streams of messages: Control, Data, etc…
• Each stream has specific purposes and needs
• Each channel has specific delivery properties
• Coordination between streams done by application
Message delivery properties

- **Fifo**: deliveries in the same order as emissions → point to point consistency.
- **Causal**: questions delivered prior to answers → global consistency.
- **Total**: deliveries in the same order for all receivers → duplicated variables.
Our contribution

Standart protocols
• Disjoint streams of messages.
• Specific delivery properties for each stream

Multimodal protocols
• Overlapping streams of messages
• Coordinate different delivery relations
• Behavioural model and implementation
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Messages and events

I set of instances

M messages

Src : M → I , Dest : M → 2^I

E events , E = { send(m) , deliver(j,m),.. }

• send(m) executed by Src(m)
• deliver(j,m) executed by j iff j in Dest(m)
Causal ordering of events

Set of events E:

\[ \text{send}(m), \text{deliver}(j, m) \] j in \text{Dest}(m)

Partial order on E: \( e \leq e' \) (causal order)

- \( \leq \) is a total order on the events of each single participant
- for each message m and destination j: \( \text{send}(m) \leq \text{deliver}(j, m) \)
Causally ordered behaviours
Causal order delivery

For all \( m, m' \),
For all \( j \) in \( \text{Dest}(m) \cap \text{Dest}(m') \)

\[
\text{Send}(m) \leq \text{Send}(m') \Rightarrow \\
\text{Deliver}(j,m) \leq \text{Deliver}(j,m')
\]
Fifo order delivery

For all \( m, m' \), such that \( \text{Src}(m) = \text{Src}(m') \)
For all \( j \) in \( \text{Dest}(m) \cap \text{Dest}(m') \)

\[ \text{Send}(m) \leq \text{Send}(m') \implies \text{Delivery}(j,m) \leq \text{Delivery}(j,m') \]
Total order delivery

For all $m, m'$,
For all $i, j$ in $\text{Dest}(m) \cap \text{Dest}(m')$

$\text{Delivery}(i, m) \leq \text{Delivery}(i, m') \Rightarrow$
$\text{Delivery}(j, m) \leq \text{Delivery}(j, m')$
Causal delivery
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Multiple delivery properties

• Agents exchange different streams of messages, each with specific delivery properties

• Messages from different streams may be related by delivery constraints.

• Allow a message have different delivery constraints with different other messages
Mixing causal orders
Relative causal order

Causality induced by a subset $M'$ of $M$

$E_{M'} = \{ \text{send}(m), \text{deliver}(j,m) : m \text{ in } M' \}$

A causal order $\leq_{M'}$ on $E_{M'}$

- $\leq_{M'}$ is locally a total order
- for each message $m$ in $M'$ and destination $j$: $\text{send}(m) \leq_{M'} \text{deliver}(j,m)$

$\leq_{M'}$ strictly included in $\leq_{M' \times M'}$
Relative causal order delivery

For all $m, m' \in M'$
For all $j$ in $\text{Dest}(m) \cap \text{Dest}(m')$

$\text{Send}(m) \leq_{M} \text{Send}(m') \implies \text{Deliver}(j,m) \leq_{M'} \text{Deliver}(j,m')$
Multiple causal orders

\[ M' = \{m1, m4, m5\} \quad M'' = \{m2, m3, m6\} \]
Overlapping causal orders

M(c1) = m1, m4, m5
M(c2) = m2, m3, m6
M(c3) = m5, m6
Multiple delivery properties

- A single message may be related to other messages by different delivery properties
- Overlapping sets of messages with proper delivery property.
Abstract channels

A subset of messages with same set of destinations and related by a specific delivery property

Abstract channel c:
- A subset of connected agents: \text{Memb}(c)
- A delivery property: \text{Mode}(c)
- A set of messages: \text{Mess}(c)
Abstract channels

• An agent may be connected to many channels
  \[ \text{Memb}(c) \cap \text{Memb}(c') \neq \emptyset \]
• A message \( m \) may belong to many channels

  \( \text{Chan}(m) \) is a set of channels

  \[ \text{Dest}(m) = \bigcup \left\{ \text{Memb}(c), c \in \text{Chan}(m) \right\} \]
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- **Multimodal communication**
Multimodal system

\[ S = (I, C, \text{Memb}, \text{Mode}) \]

- **I**: instances
- **C**: channels
- **Memb**: $C \rightarrow 2^I$, **Ch**: $I \rightarrow 2^C$
- **Mode**: $C \rightarrow \{\text{none, fifo, causal}\}$

**M** set of messages

- **Src**: $M \rightarrow I$
- **Chan**: $M \rightarrow 2^C$, **Mess**: $C \rightarrow 2^M$
Multimodal events

\[
\text{send}(i,m,C')
\]

- \(i = \text{Src}(m), C' = \text{Chan}(m)\)
- All \(c\) in \(\text{Chan}(m)\) belong to \(\text{Ch}(i)\) (i is connected to all \(\text{Chan}(m)\))

\[
\text{deliver}(j,m)
\]

- Some \(c\) in \(\text{Chan}(m)\) belongs to \(\text{Ch}(j)\) (i is connected to some \(\text{Chan}(m)\))
- A single delivery for any \(j\) in \(\text{Dest}(m)\)
Multi-modal delivery

For any channel $c$ of $\text{Chan}(m)$, $m$ is delivered in $\text{Mode}(c)$ w.r.t. the other messages of $\text{Mess}(c)$

- on every instance $j$ of $\text{Memb}(c)$ if $\text{Mode}(c)$ is fifo or causal
- on every pair of instances $j,k$ of $\text{Memb}(c)$ if $\text{Mode}(c)$ is total
Causal delivery

For all \( m, m' \) in \( \text{Mess}(c) \)
For all \( j \) in \( \text{Memb}(c) \)

\[
\text{Send}(m) \leq_{\text{Mess}(c)} \text{Send}(m') \Rightarrow \\
\text{Deliver}(j,m) \leq_{\text{Mess}(c)} \text{Deliver}(j,m')
\]
Fifo delivery

For all $m, m'$ in Mess(c)
For all $i, j$ in Memb(c)

$\text{Send}(i, m) \leq \text{Send}(i, m') \Rightarrow \text{Deliver}(j,m) \leq \text{Deliver}(j,m')$
Total order delivery

For all $m, m'$ in $\text{Mess}(c)$
For all $i, j$ in $\text{Memb}(c)$

$\text{Deliver}(i, m) \leq \text{Deliver}(i, m') \implies \text{Deliver}(j, m) \leq \text{Deliver}(j, m')$
Example 1
Example 2
Example 3
Example 4
Multimodal protocols

send(m,\{c_1, c_2\})

deliver(m,\{c_2\})

deliver(m,\{c_1, c_2\})

(m, \text{info}(c_1), \text{info}(c_2))
Conclusion

• Flexible communication capacities
• Tuned precisely to application needs
• Extended aspect of causality
• Reuse of existing algorithms and protocols (Enseeiht Toulouse : Java Groups)
• Causal Streams Algebra
Thank You