Keynote: From groupware to large-scale trustworthy distributed collaborative systems

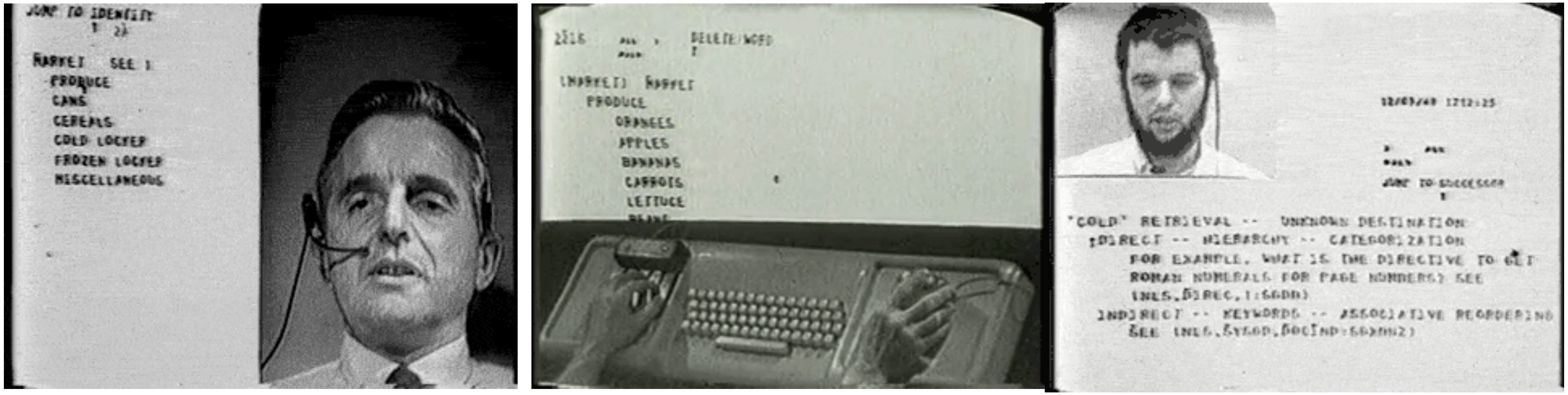
Claudia-Lavinia Ignat

From groupware to large-scale trustworthy distributed collaborative systems

Claudia-Lavinia Ignat, Inria, France

CRIWG 2018
September 5, 2018
claudia.ignat@inria.fr

Douglas Engelbart: Augmenting Human Intellect



The Mother of all Demos, December 9, 1968

NLS: Online System

https://archive.org/details/dougengelbartarchives

Groupware, early 1990s

- « Computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment. » [EGR91]
- Lotus Notes, one of the first commercial groupware allowing remote group collaboration

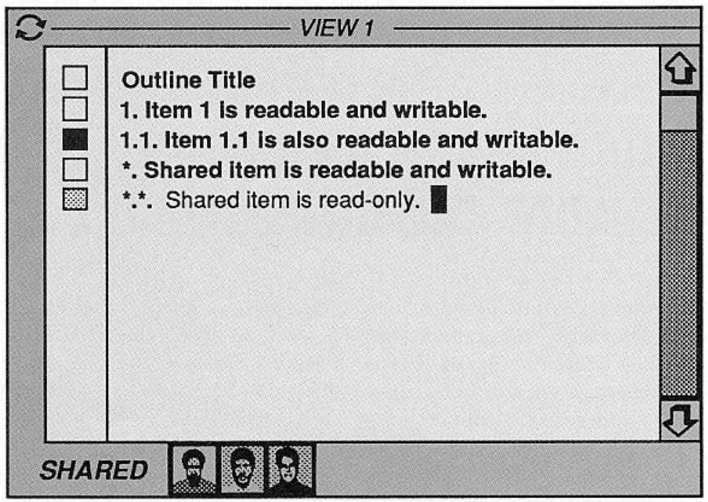
Groupware Time Space Matrix [J88]

Time/Space Groupware Matrix

	same time synchronous	**different time** asynchronous
same place co-located	**Face to face interactions** decision rooms, single display groupware, **shared table**, wall displays, roomware, …	**Continuous task** **large public display**, team rooms, shift work groupware, project management, …
different place remote	**Remote interactions** video conferencing, instance messaging, **chats**/MUDs/virtual worlds, shared screens, **multi-user editors** , …	**Communication + coordination** email, bulletin boards, blogs, asynchronous conferencing, group calendars, workflow, **version control**, **wikis**, …

Groupware: supported solutions

- *Turn taking*: allow only one active participant at a time
  - e.g. *RTCAL* [SG88], *SHARE* [G90]
- *Locking*: concurrent editing allowed only if users lock and edit different objects
  - e.g. *Colab* [SFBKLS88]



- *Operational transformation*
  - e.g. *GROVE* [EG89]

Google Drive

March 2006
Writely
(Google Docs)

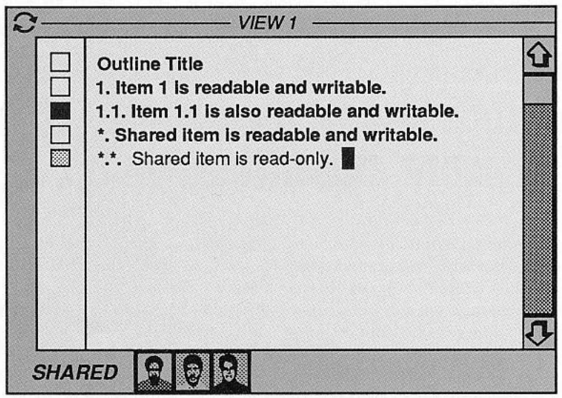
June 2006
XL2Web
(Google Sheets)

September 2007
Google Slides

2012
Google Drive

Collaborative Systems: from users to community of users

"Isn't it chaotic to all edit in the same document, even the same paragraph, at the same time?"
"Why would a group ever want to edit in the same line of text at the same time?" [EGR91]



GROVE, 1989

Collaborative Systems: from users to community of users

2013: MOOC "Fundamentals of Online Education: Planning and Applications" with 40.000 participants

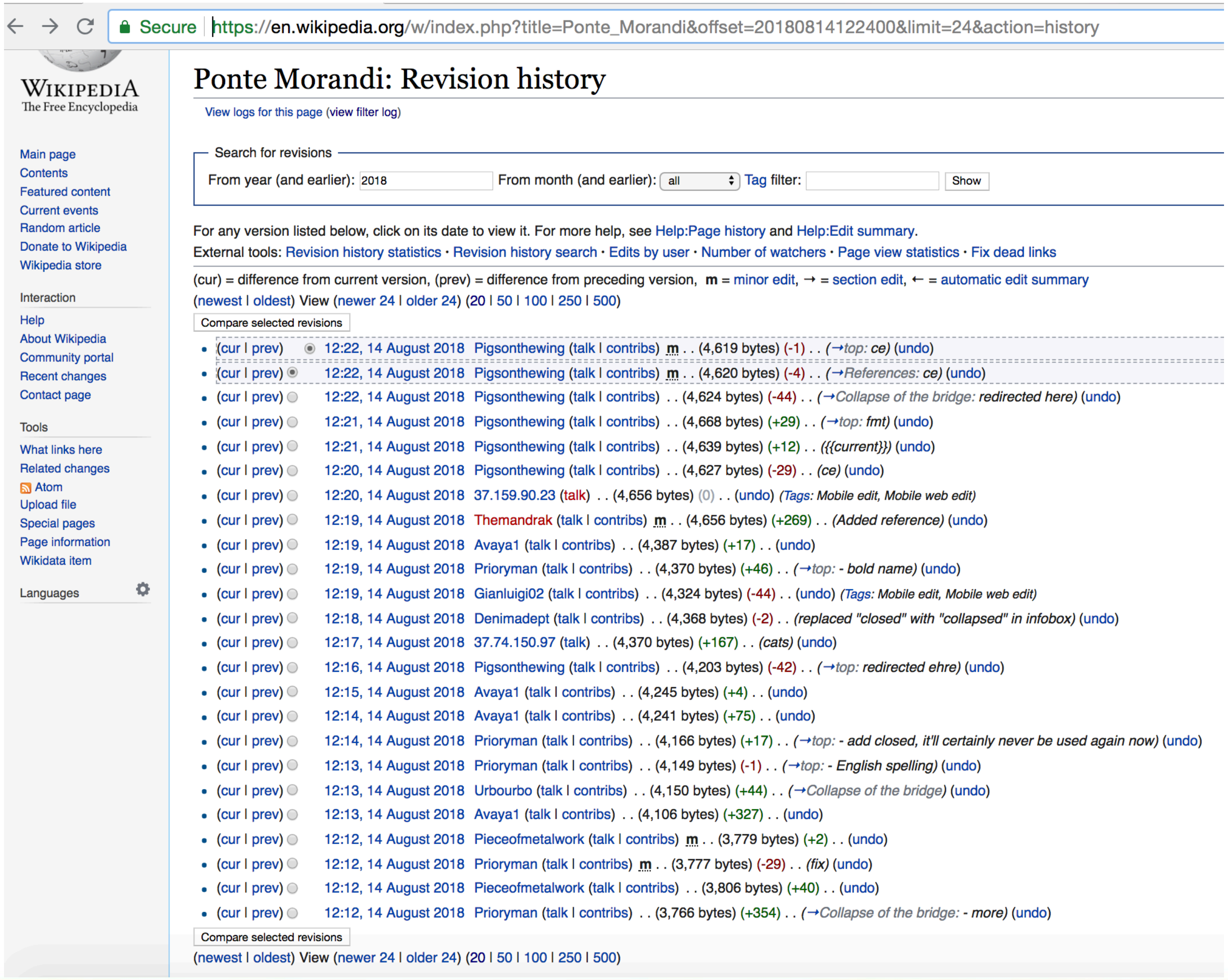
2016: Nuit debout, more than 70 people edit a pad

2018: online CSCW PC meeting with 120 members

Collaborative Systems: from users to community of users

Real-time

Wikipedia



Secure | https://en.wikipedia.org/w/index.php?title=Ponte_Morandi&offset=20180814122400&limit=24&action=history

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Featured content
Current events
Random article
Donate to Wikipedia
Wikipedia store

Interaction
Help
About Wikipedia
Community portal
Recent changes
Contact page

Tools
What links here
Related changes
Atom
Upload file
Special pages
Page information
Wikidata item

Languages

Ponte Morandi: Revision history

View logs for this page (view filter log)

Search for revisions
From year (and earlier): 2018 From month (and earlier): all Tag filter: Show

For any version listed below, click on its date to view it. For more help, see Help:Page history and Help:Edit summary.
External tools: Revision history statistics · Revision history search · Edits by user · Number of watchers · Page view statistics · Fix dead links

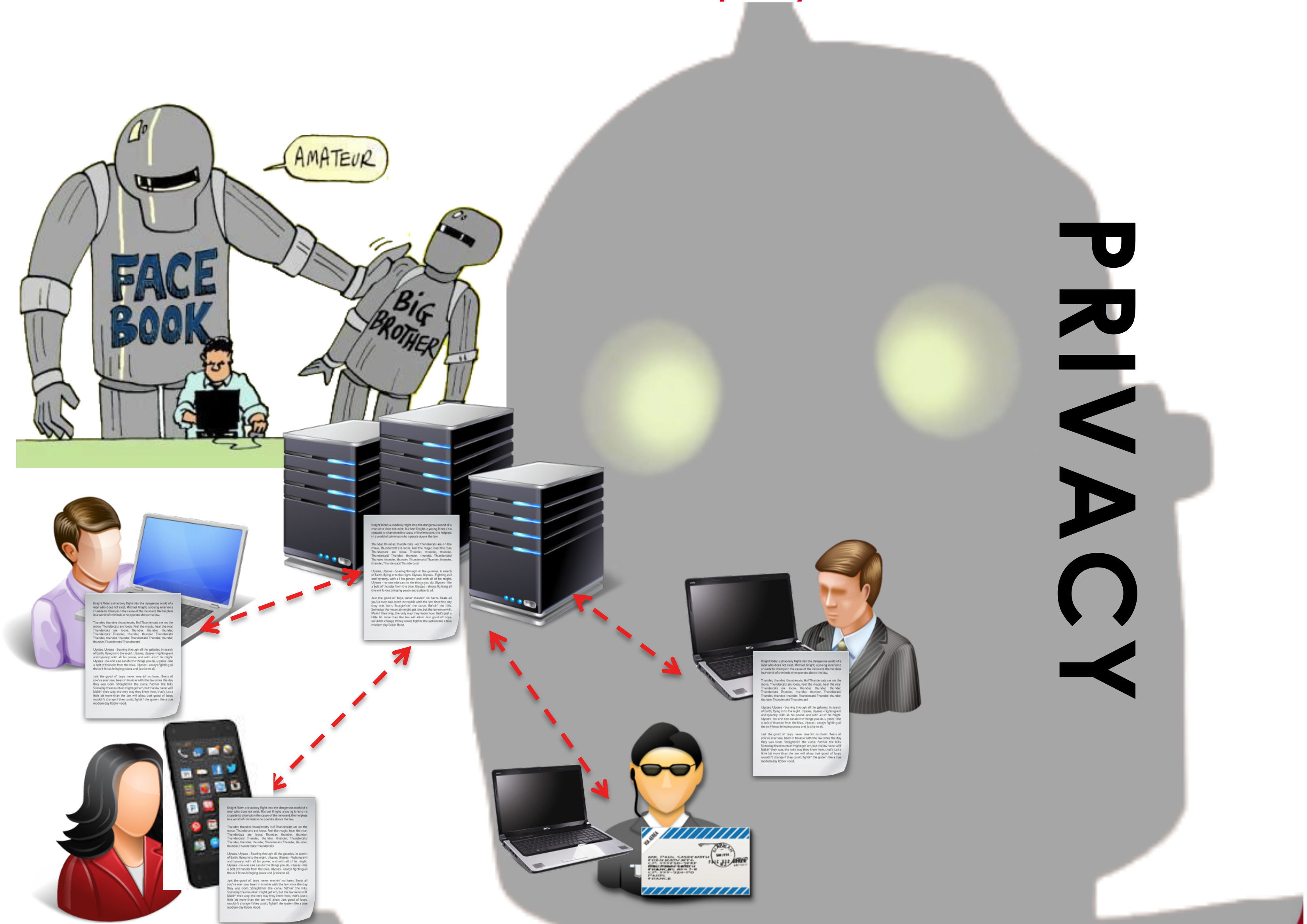
(cur) = difference from current version, (prev) = difference from preceding version, m = minor edit, → = section edit, ← = automatic edit summary
(newest | oldest) View (newer 24 | older 24) (20 | 50 | 100 | 250 | 500)
Compare selected revisions

- (cur | prev) 12:22, 14 August 2018 Pigsonthewing (talk | contribs) m . . (4,619 bytes) (-1) . . (→top: ce) (undo)
- (cur | prev) 12:22, 14 August 2018 Pigsonthewing (talk | contribs) m . . (4,620 bytes) (-4) . . (→References: ce) (undo)
- (cur | prev) 12:22, 14 August 2018 Pigsonthewing (talk | contribs) . . (4,624 bytes) (-44) . . (→Collapse of the bridge: redirected here) (undo)
- (cur | prev) 12:21, 14 August 2018 Pigsonthewing (talk | contribs) . . (4,668 bytes) (+29) . . (→top: fmt) (undo)
- (cur | prev) 12:21, 14 August 2018 Pigsonthewing (talk | contribs) . . (4,639 bytes) (+12) . . ({{current}}) (undo)
- (cur | prev) 12:20, 14 August 2018 Pigsonthewing (talk | contribs) . . (4,627 bytes) (-29) . . (ce) (undo)
- (cur | prev) 12:20, 14 August 2018 37.159.90.23 (talk) . . (4,656 bytes) (0) . . (undo) (Tags: Mobile edit, Mobile web edit)
- (cur | prev) 12:19, 14 August 2018 Themandrak (talk | contribs) m . . (4,656 bytes) (+269) . . (Added reference) (undo)
- (cur | prev) 12:19, 14 August 2018 Avaya1 (talk | contribs) . . (4,387 bytes) (+17) . . (undo)
- (cur | prev) 12:19, 14 August 2018 Prioryman (talk | contribs) . . (4,370 bytes) (+46) . . (→top: - bold name) (undo)
- (cur | prev) 12:19, 14 August 2018 Gianluigi02 (talk | contribs) . . (4,324 bytes) (-44) . . (undo) (Tags: Mobile edit, Mobile web edit)
- (cur | prev) 12:18, 14 August 2018 Denimadept (talk | contribs) . . (4,368 bytes) (-2) . . (replaced "closed" with "collapsed" in infobox) (undo)
- (cur | prev) 12:17, 14 August 2018 37.74.150.97 (talk) . . (4,370 bytes) (+167) . . (cats) (undo)
- (cur | prev) 12:16, 14 August 2018 Pigsonthewing (talk | contribs) . . (4,203 bytes) (-42) . . (→top: redirected ehre) (undo)
- (cur | prev) 12:15, 14 August 2018 Avaya1 (talk | contribs) . . (4,245 bytes) (+4) . . (undo)
- (cur | prev) 12:14, 14 August 2018 Avaya1 (talk | contribs) . . (4,241 bytes) (+75) . . (undo)
- (cur | prev) 12:14, 14 August 2018 Prioryman (talk | contribs) . . (4,166 bytes) (+17) . . (→top: - add closed, it'll certainly never be used again now) (undo)
- (cur | prev) 12:13, 14 August 2018 Prioryman (talk | contribs) . . (4,149 bytes) (-1) . . (→top: - English spelling) (undo)
- (cur | prev) 12:13, 14 August 2018 Urbourbo (talk | contribs) . . (4,150 bytes) (+44) . . (→Collapse of the bridge) (undo)
- (cur | prev) 12:13, 14 August 2018 Avaya1 (talk | contribs) . . (4,106 bytes) (+327) . . (undo)
- (cur | prev) 12:12, 14 August 2018 Pieceofmetalwork (talk | contribs) m . . (3,779 bytes) (+2) . . (undo)
- (cur | prev) 12:12, 14 August 2018 Prioryman (talk | contribs) m . . (3,777 bytes) (-29) . . (fix) (undo)
- (cur | prev) 12:12, 14 August 2018 Pieceofmetalwork (talk | contribs) . . (3,806 bytes) (+40) . . (undo)
- (cur | prev) 12:12, 14 August 2018 Prioryman (talk | contribs) . . (3,766 bytes) (+354) . . (→Collapse of the bridge: - more) (undo)

Compare selected revisions
(newest | oldest) View (newer 24 | older 24) (20 | 50 | 100 | 250 | 500)

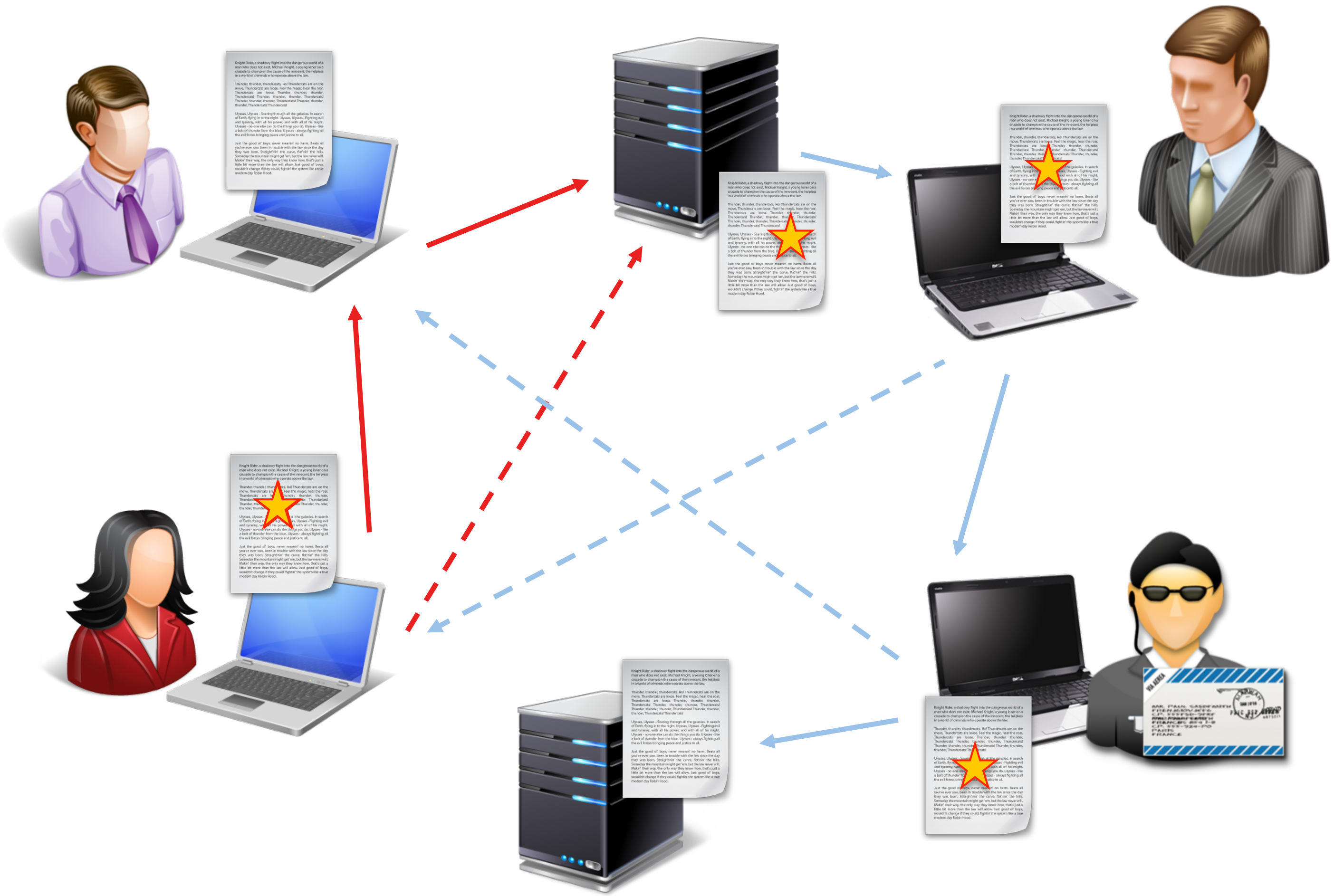
Limitations of Central Authority Systems

SCALABILITY

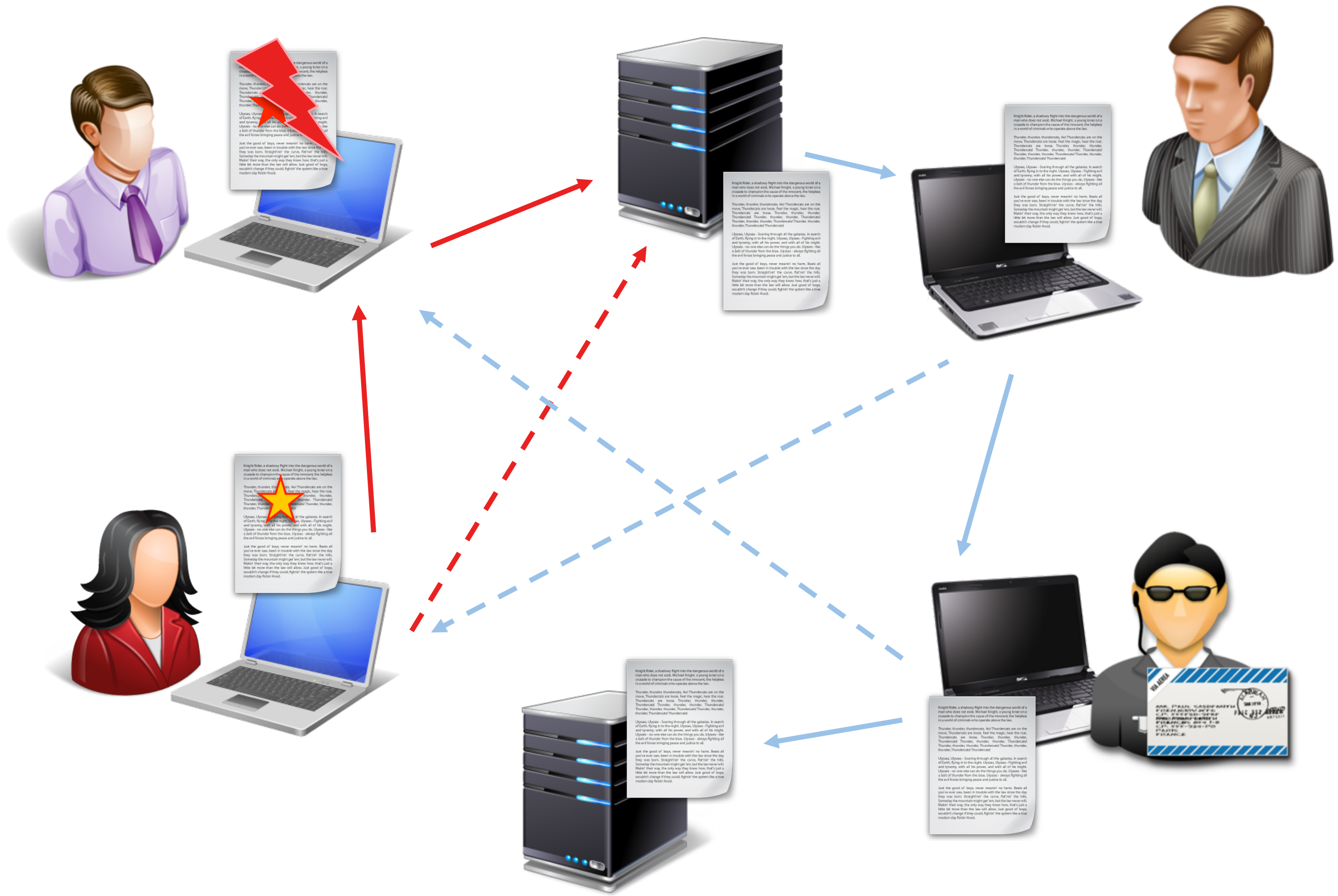


PRIVACY

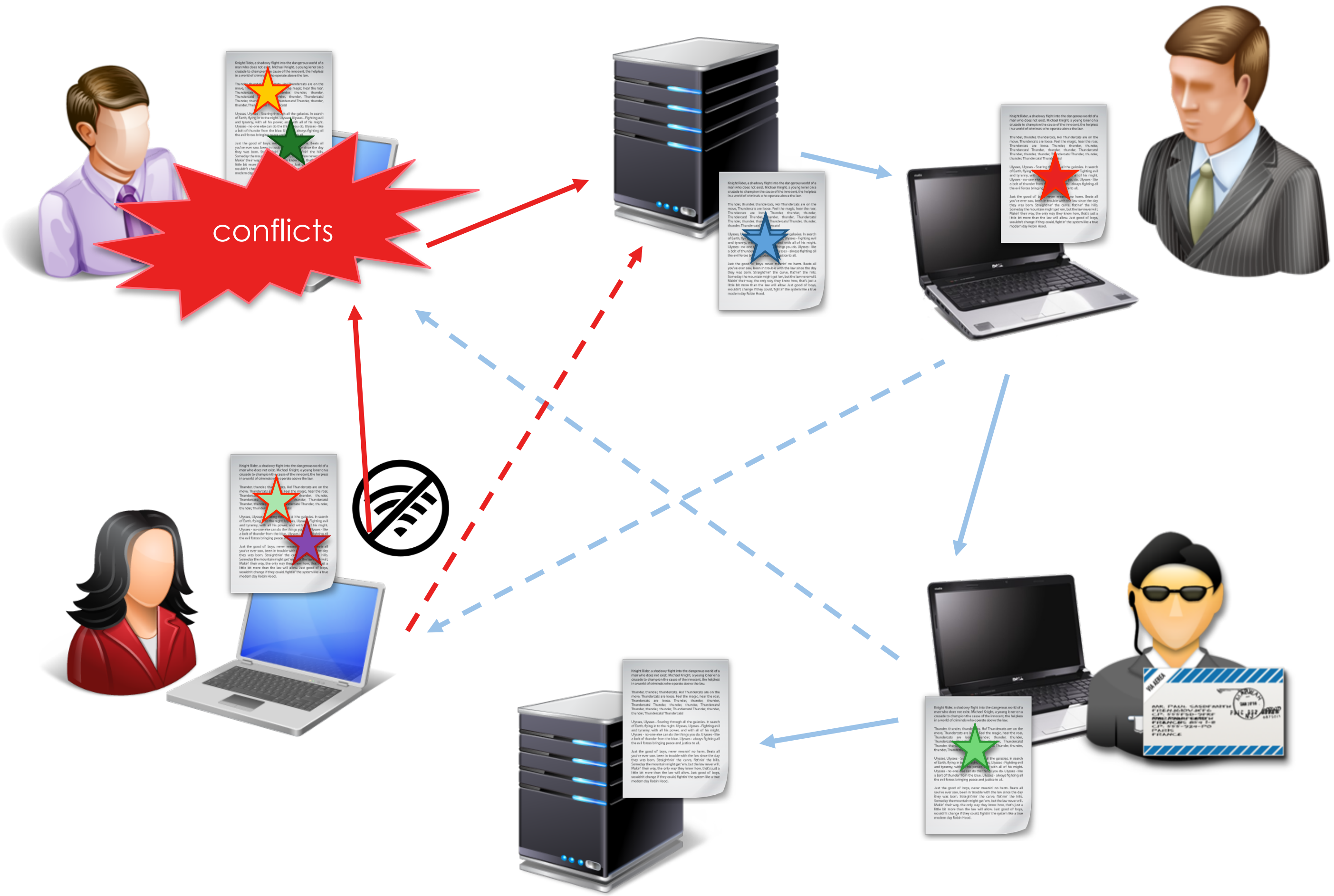
Peer-to-Peer Collaborative Systems



Collaboration Modes – Concurrent Changes



Collaboration Modes – Offline Work



Collaboration Modes – Ad-hoc Collaboration

Research issues

1 How to **maintain consistency of different copies** in the face of concurrent modifications?

2 How to **evaluate the design of collaborative systems** and approaches?

3 How to **secure collaboration data**?

Research issues

1 How to **maintain consistency of different copies** in the face of concurrent modifications?

2 How to **evaluate the design of collaborative systems and approaches?**

3 How to **secure collaboration data?**

Optimistic Replication [SS05]

- Trade-off between consistency and availability
  - Optimistic replication : allows replicas to diverge
- Strong Eventual Consistency
  - Eventual delivery: An update executed at some correct replica eventually executes at all correct replicas
  - Strong convergence: Correct replicas that have executed the same updates have equivalent states
  - No consensus in background, no need to rollback
- Intention preservation
  - « *Effect of each operation should be observed on all copies* »

Operational transformation (OT) [EG89]

- *n* copies of an object hosted at *n* sites
- An object is modified by applying operations

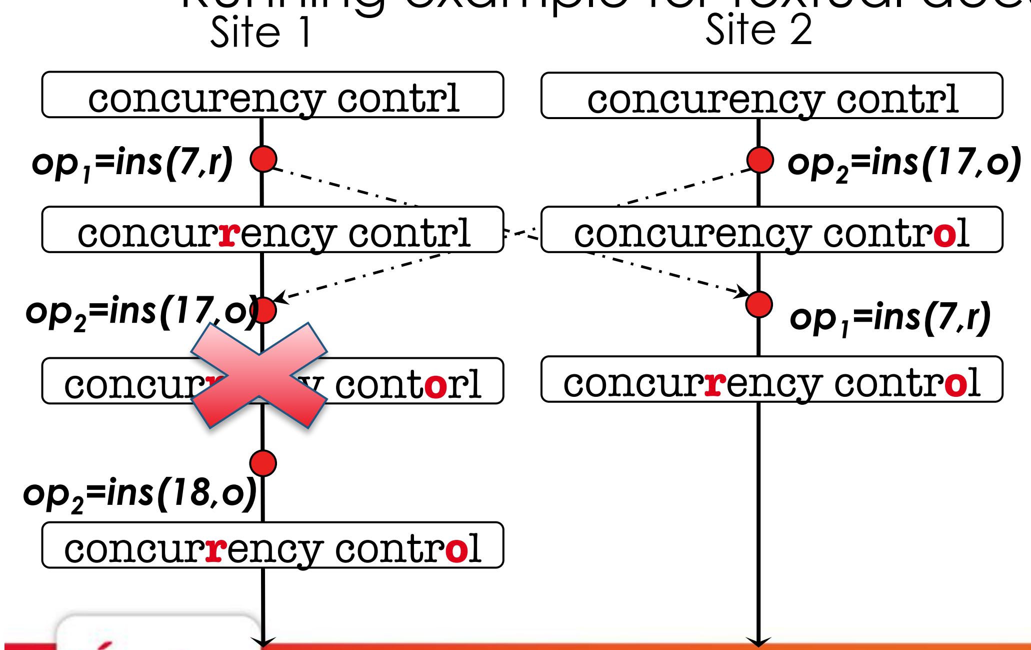
- Each operation is
  - generated at a site (local execution), and applied immediately on the local copy
  - broadcasted to other sites
  - integrated at those sites (remote execution)

- System is correct if when it is idle all copies are identical (SEC)

Operational transformation (OT)

- General architecture with two main components:
  - An integration algorithm (diffusion, integration)
  - A set of transformation functions (conflict resolution)

- Running example for textual document = sequence of characters

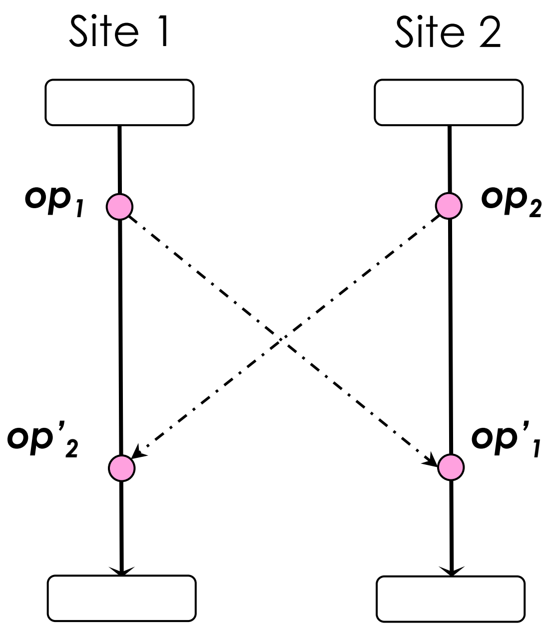


- Operations:
  - ins(p, c)
  - del(p)

T(ins(p1,c1), ins(p2,c2)) :-
  if (p1<p2) return ins(p1,c1)
  else return ins(p1+1,c1)
  endif

Operational transformation
Correctness [EG89]

$$\text{(TP1)} \quad op_1 \circ T(op_2, op_1) \equiv op_2 \circ T(op_1, op_2)$$

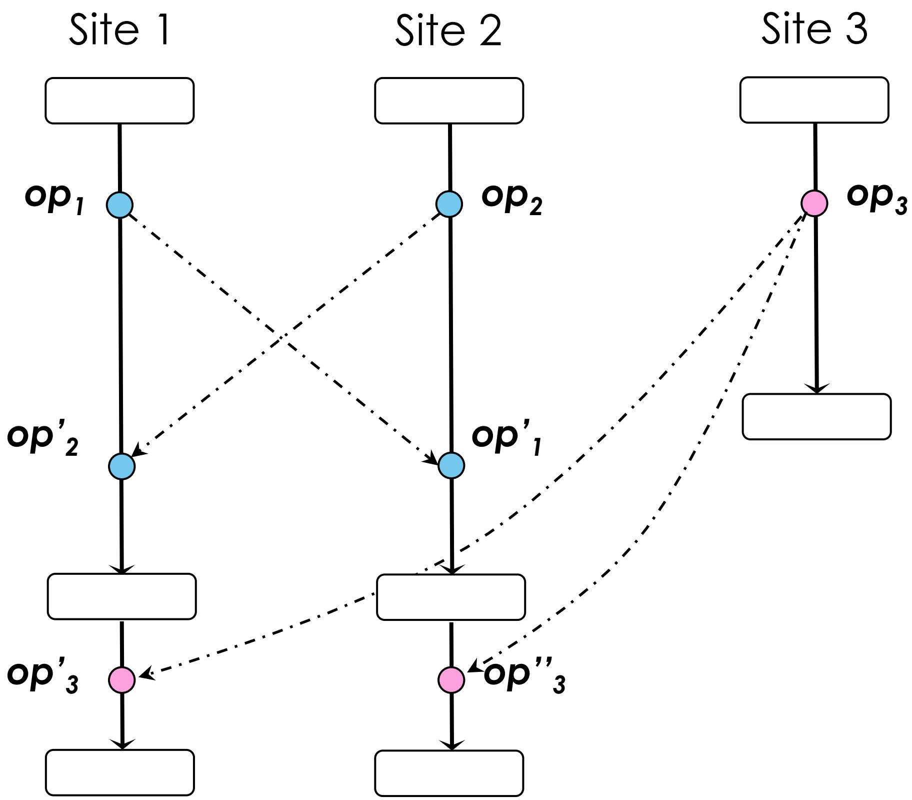


T(op_2: operation, op_1: operation) = op'_2

- op_1 and op_2 concurrent, defined on a state S
- op'_2 same effects as op_2, defined on S.op_1

Operational transformation
Correctness [RNG96]

(TP2) $T(op_3, op_1 \circ T(op_2, op_1)) = T(op_3, op_2 \circ T(op_1, op_2))$



Operational transformation (OT)
Existing approaches

- Two main families:
  - Transformation functions satisfying both TP1 and TP2: SOCT2 [SCF97] + TTF [OUMI06]
  - Control algorithms avoiding (needs of) TP2: SOCT4 [VCFS00], Jupiter [NCDL95]

Operational transformation (OT)
Summary

- Transforms non commuting operations to make them commute
- Genericity
- Time complexity
  - Average: $O(H\ c)$ H: #ops
  - Worst case: $O(H^2)$ c: avg. #conc. ops
- Difficult to write correct transformation functions
- State vectors used for detecting concurrency ⇒ scalability limitations
- **Not very suitable for large scale peer-to-peer collaboration**

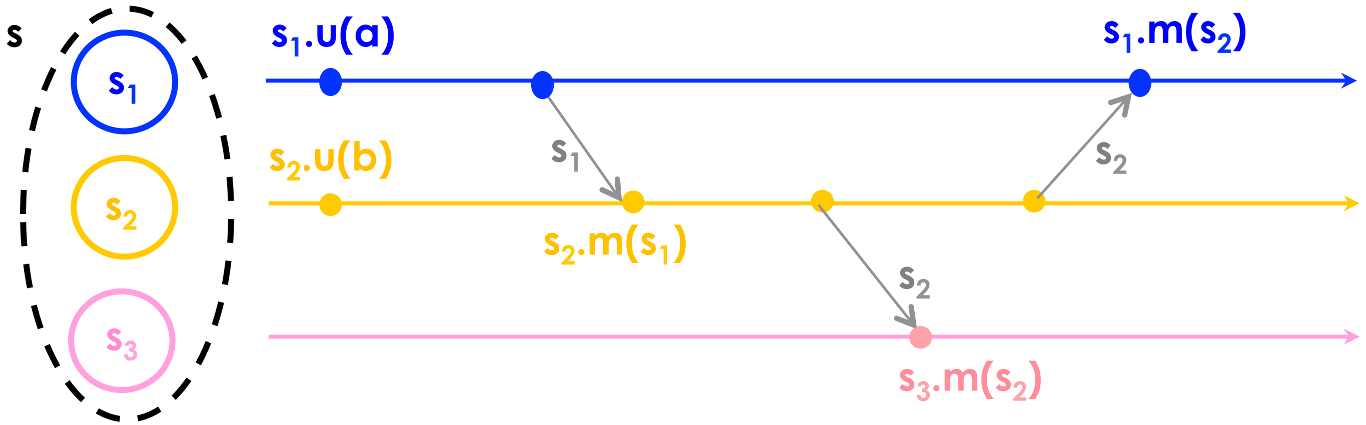
Conflict-free Replicated Data Types (CRDT) [SPBZ11]

- Design operations to be commutative by construction

- Abstract data types
  - Designed to be replicated at multiple sites
  - Any replica can be modified without coordination
  - State convergence is guaranteed

- State-based and operation-based approaches

Conflict-free Replicated Data Types (CRDT)
State-based Replication



- Algorithm
  - Periodically, replica at p_i sends its current state to p_j
  - Replica p_j merges received state into its local state by executing m
- After receiving all updates (irrespective of order), each replica will have same state

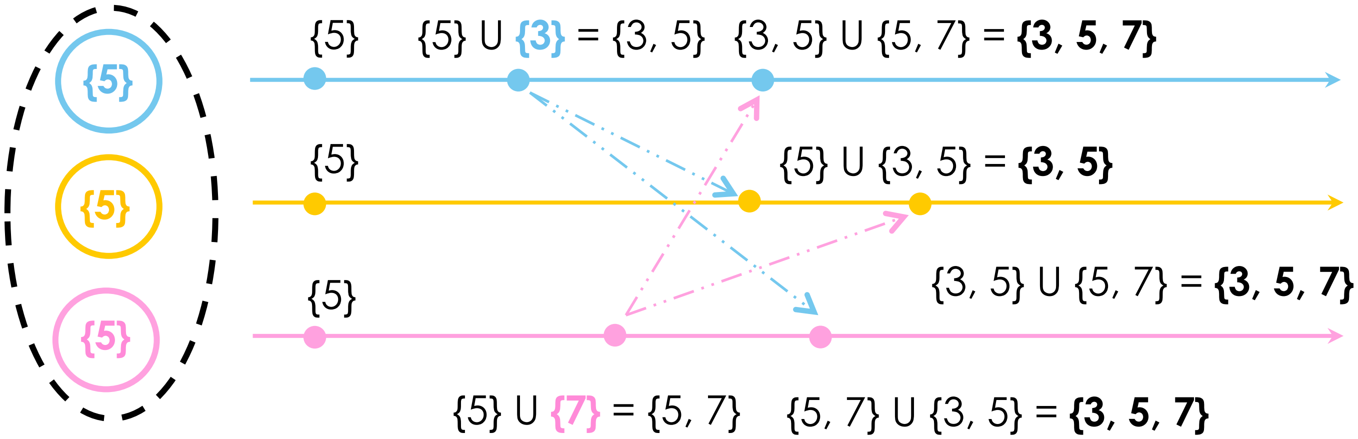
Conflict-free Replicated Data Types (CRDT) State-based Replication

- Merge operator:
  - **Commutative**: $x \bullet y = y \bullet x$
  - **Associative**: $(x \bullet y) \bullet z = x \bullet (y \bullet z)$
  - **Idempotent** : $x \bullet x = x$

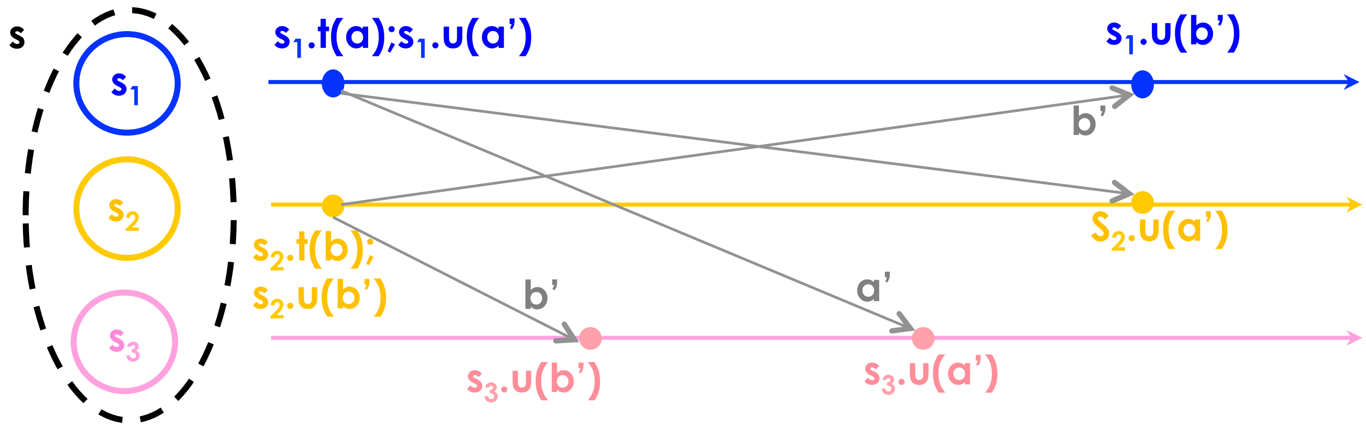
- A semi-lattice is a Partial order $\leq$ set S with a least upper bound (LUB), denoted $\sqcup$
  - $m = x \sqcup y$ is a LUB of $\{ x, y \}$ under $\leq$ if and only if
    $\forall m', x \leq m' \wedge y \leq m' \Rightarrow x \leq m \wedge y \leq m \wedge m \leq m'$
  - It follows that $\sqcup$ is commutative, associative and idempotent

Conflict-free Replicated Data Types (CRDT)
Convergent Replicated Data Type (CvRDT)

- Example



Conflict-free Replicated Data Types (CRDT) Operation-based Replication



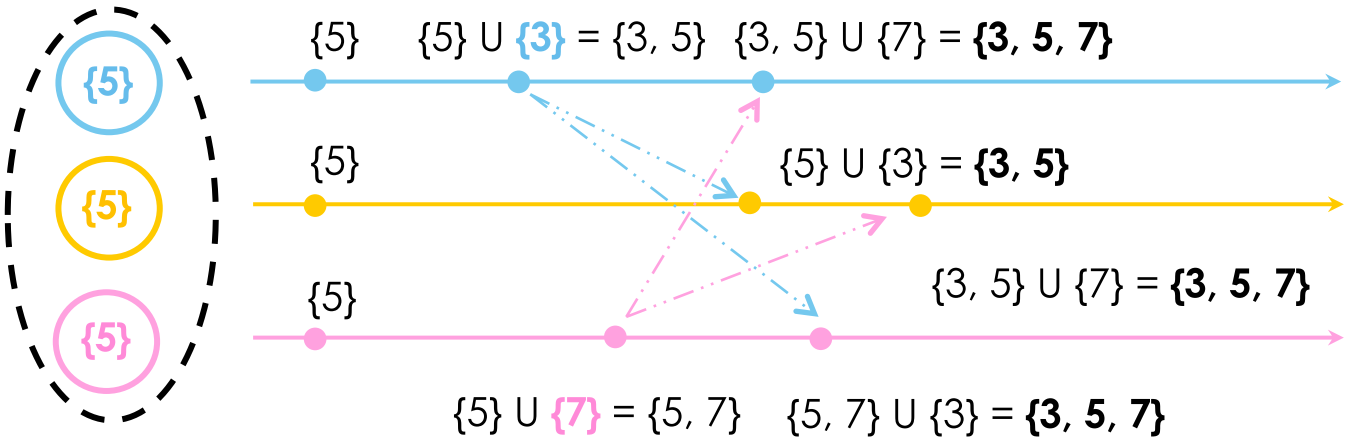
- An update split into *(t,u)*: *t* is a side-effect-*free prepare-update method* and *u* is an *effect-update* method

- Algorithm
  - Updates delivered to all replicas
  - Causally-ordered broadcast, every message delivered to every node exactly once w.r.t. happen-before order

- Commutativity holds for concurrent updates

Conflict-free Replicated Data Types (CRDT)
Commutative Replicated Data Type (CmRDT)

- Example



Conflict-free Replicated Data Types (CRDT) CvRDT vs. CmRDT

- Both approaches are equivalent
  - A state-based object can emulate an operation-based object, and vice-versa

- Operation-based:
  - More efficient since you only ship small updates
  - But require exactly once causally-ordered broadcast

- State-based:
  - Only require reliable broadcast
  - Communication overhead of shipping the whole state

- Delta State-based [ASB18]:
  - Small messages
  - Dissemination over unreliable communication channels

Consistency Maintenance
Conflict-free Replicated Data Types (CRDT)

- Register
  - Last-Writer Wins
  - Multi-Value
- Set
  - Grow-Only
  - 2-Phase
  - Observed-Remove
  - Observed-Update-Remove

- Map
- Counter
- Graph
  - Directed
  - Monotonic DAG
  - Edit graph
- **Sequence**

Conflict-free Replicated Data Types (CRDT) (Text) Sequence [PMSL09] [WUM09]

- Document = linear sequence of elements
  - Each element has a unique identifier
  - Identifier constant for the lifetime of the document
  - Dense total order of identifiers consistent with element order:
    - $\forall\ id_x, id_y: id_x < id_y \Rightarrow \exists\ id_z : id_x < id_z < id_y$

- Different approaches for generating identifiers:
  - TreeDoc, Logoot, LogootSplit, …

Conflict-free Replicated Data Types (CRDT)
Logoot [WUM09]

- Logoot identifiers: $<p_1,s_1,h_1><p_2,s_2,h_2> \cdots <p_k,s_k,h_k>$
  - p_i integer
  - s_i site identifier
  - h_i logical clock at site s_i

<1,2,1>	**c**
<1,2,2>	o
<2,1,2>	n
<3,1,3>	c
<3,1,3><8,4,5>	u
<3,2,5>	r
<4,1,7>	e
<4,1,7><9,2,6>	n
<7,2,8>	c
<9,1,7>	y
<10,2,8>	
<12,3,1>	c
<12,3,1><6,5,1>	o
<12,3,1><7,8,2>	n
<12,3,1><7,8,2><12,3,5>	t
<12,3,1><7,8,2><13,3,6>	r
<12,3,1><7,8,2><14,3,7>	l

ins(<3,2,5><13,1,7>, r)

ins(<12,3,1><7,8,2><13,3,6><7,2,9>, o)

- Time complexity
  - Average: O(k log(n))
  - Worst case: O(H*log(H))
  - H: #ops
  - n: doc. size (non deleted chars.)
  - k: avg. size of Logoot identifier
- No need for concurrency detection
- Identifiers storage cost
- New design for each data type
- **Suitable for large-scale collaboration**

Conflict-free Replicated Data Types (CRDT)

LogootSplit [AMOI13]

LogootSplit identifiers

Base					Interval	
p_1	…	p_n	*site_id*	*clock*	begin	end

1,1,[0,16]	concurency contrl

Insert r between “concur” and “ency contrl”

1,1,[0,5]	concur
1,1,5,2,1,[0,0]	r
1,1, [6,16]	ency contrl

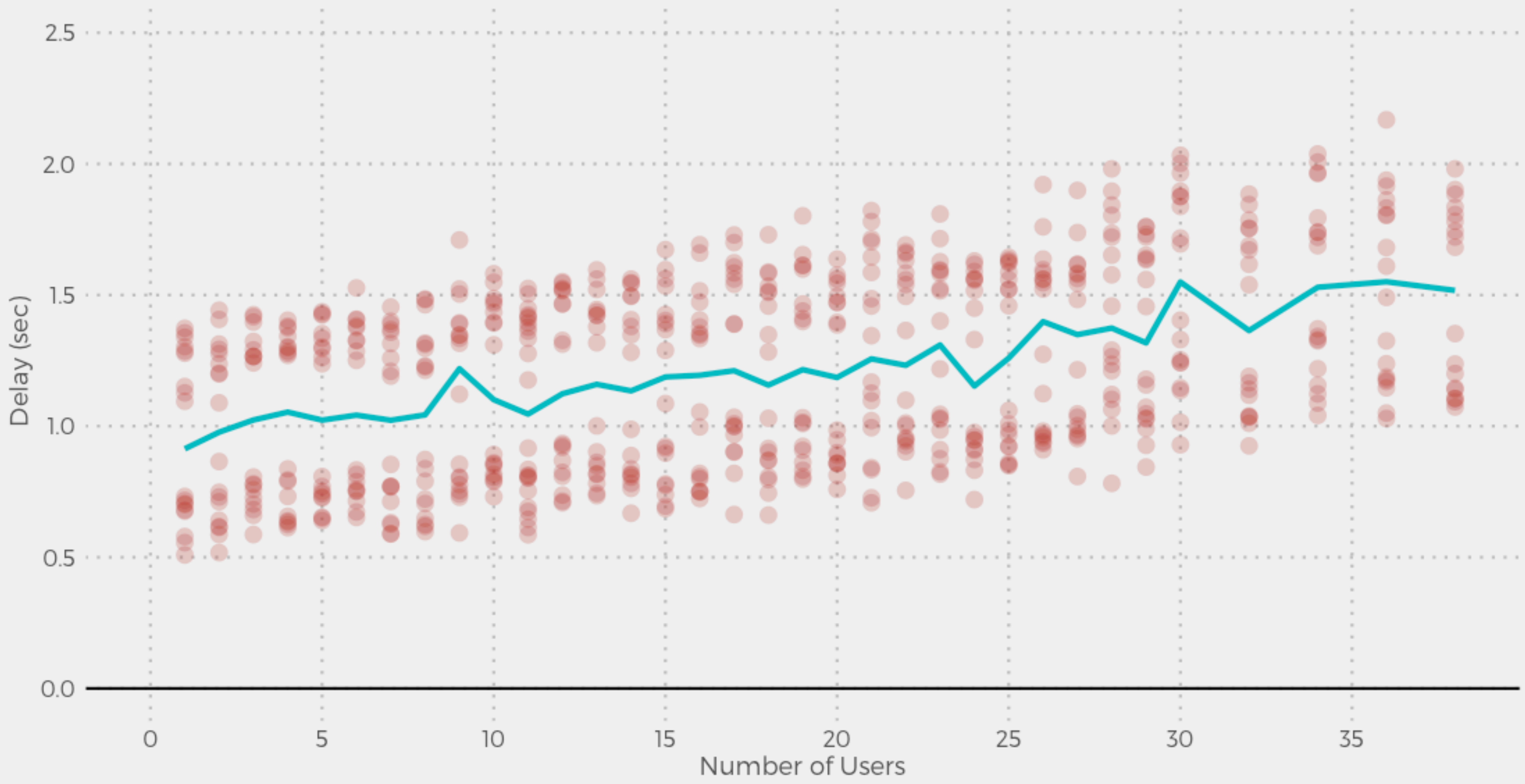
Insert o between “ency contr” and “l”

1,1,[0,5]	concur
1,1,5,2,1,[0,0]	r
1,1, [6,15]	ency contr
1,1,15,3,1,[0,0]	o
1,1,[16,16]	l

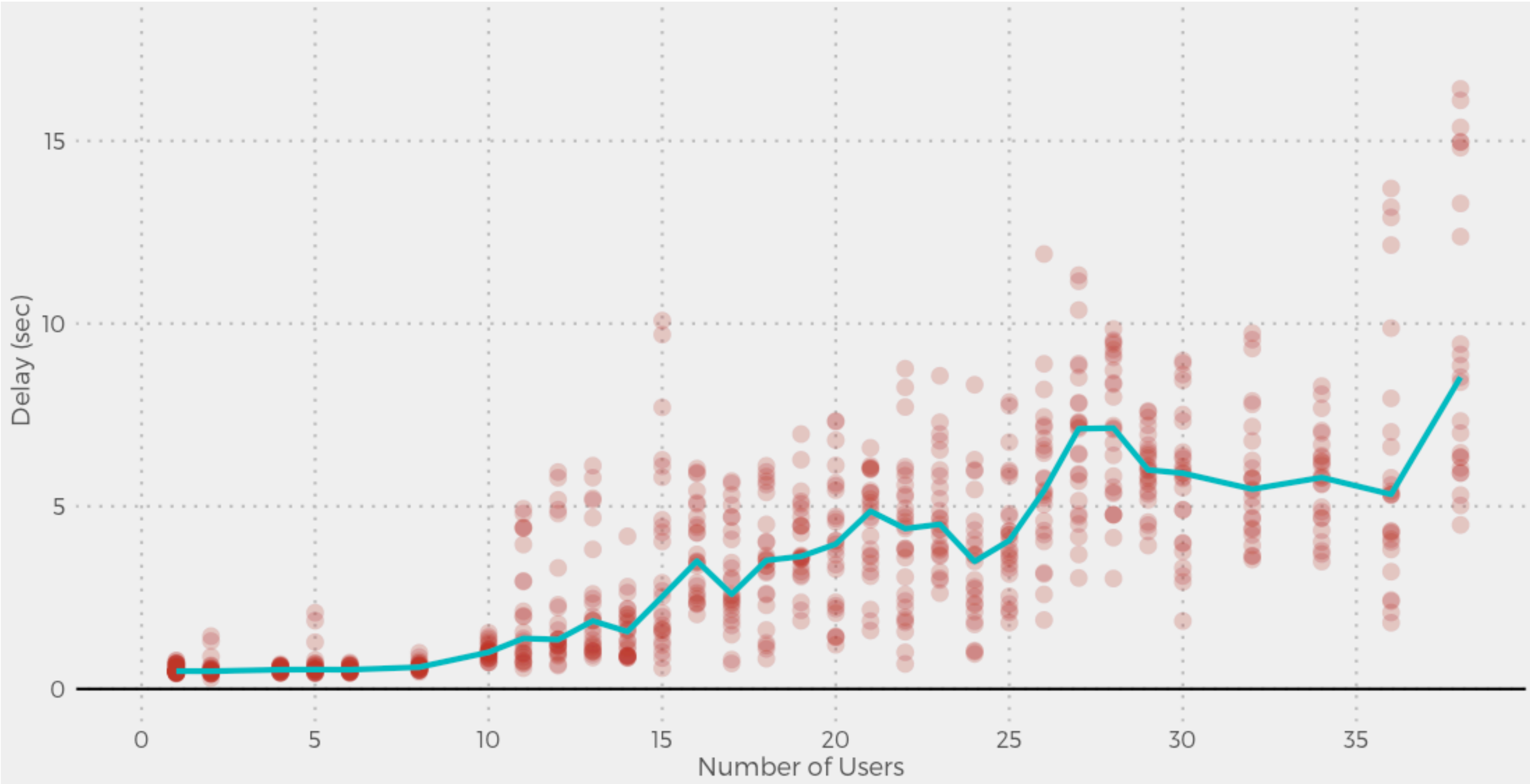
OT vs. operation-based CRDT

- CRDT: more formalised approach
- OT: more generic and guided
  - Generic concurrency control algorithm
  - Operation transformations specific to application domain
- CRDT: different solutions for concurrency handling for different data types
- CRDT: Metadata overhead

Delays in MUTE [NEOIC17] https://coedit.re/



Delays in GoogleDocs [DI16]



Research issues

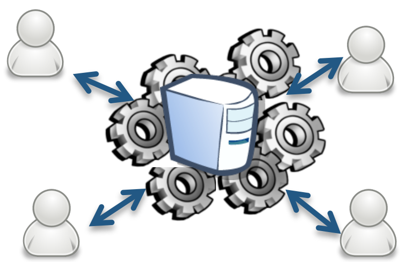
1 How to **maintain consistency of different copies** in the face of concurrent modifications?

2 How to **evaluate the design of collaborative systems** and approaches?

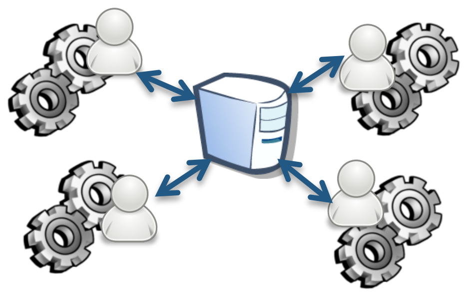
3 How to **secure collaboration data**?

User Study: The effect of delay on users

- Delays in seeing modifications of other users
  - Network delay
  - Time complexity of consistency maintenance algorithms
  - Types of architecture



Thin client architecture



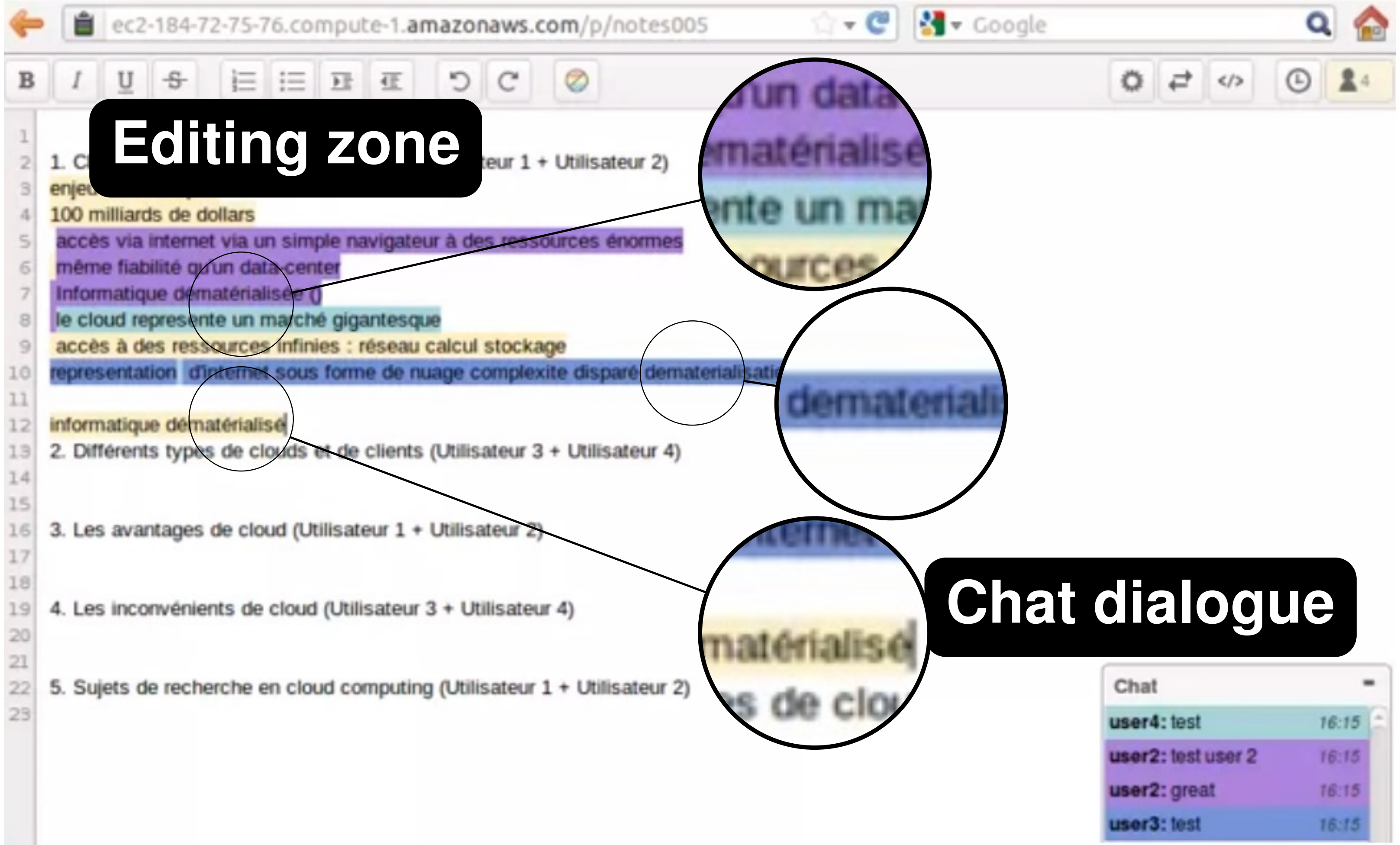
Thick client architecture

- How does **delay influence group performance**?

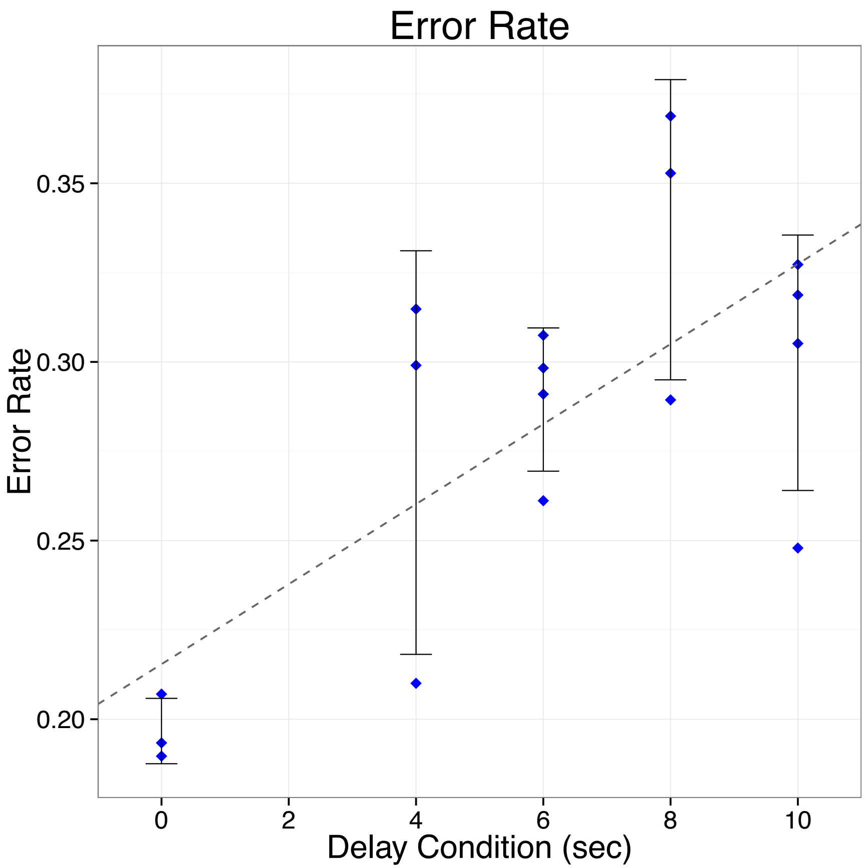
Experiment design

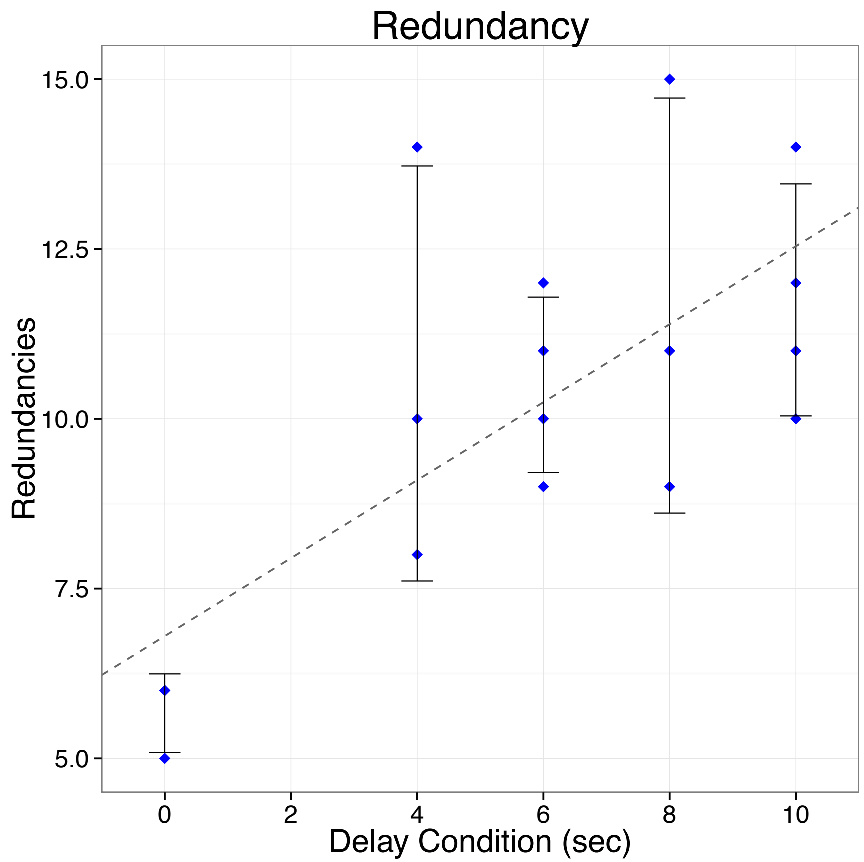
- 20 groups of 4 students
  - Perform several collaborative editing tasks
    - A proofreading task
    - A sorting task
    - **A note taking task**
  - Use the provided collaborative editor (Etherpad) + chat
  - Each group experienced a **certain delay** (0, 4, 6, 8, 10 s)
- Registration of user keyboard inputs
- Video recording of user activities on desktop

Note-taking [IOFSC15]



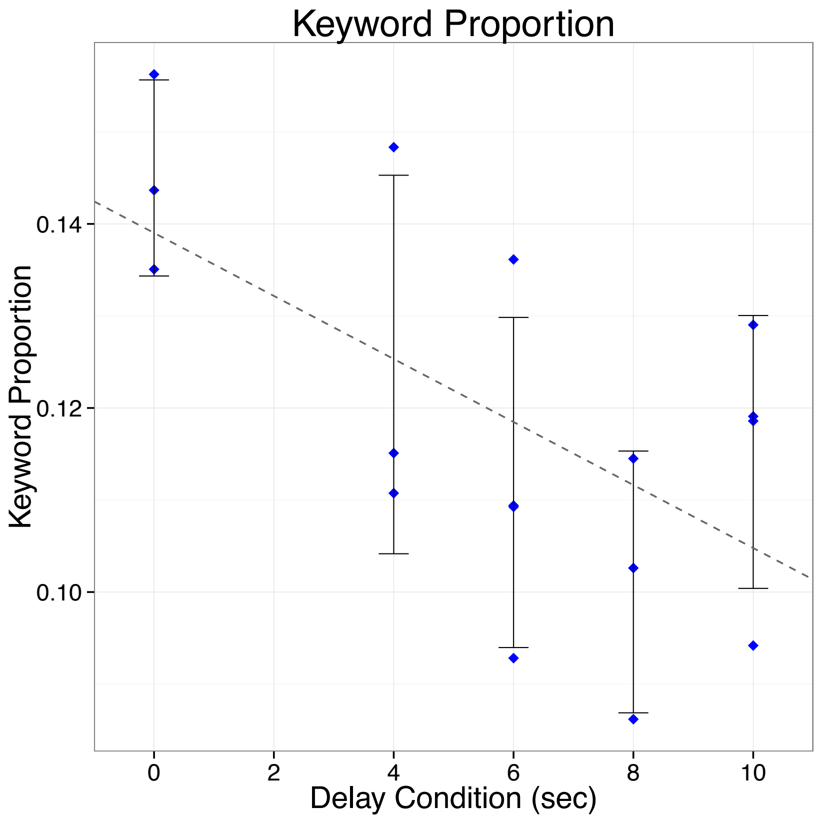
Delay reduces Group Performance





- Delay increases error rate and redundancy

Delay reduces Group Performance



- Delay decreases proportion of keywords

Design implications

- Reduce the delay by the choice of the architecture and synchronisation algorithms
- Make users aware of existing delays such that they can compensate for the delay by coordination strategies
- Analyse real collaboration traces to understand collaboration patterns and behavior [NI18]

Research issues

1 How to **maintain consistency of different copies** in the face of concurrent modifications?

2 How to **evaluate the design of collaborative systems** and approaches?

3 How to **secure collaboration data**?

Security in peer-to-peer collaboration

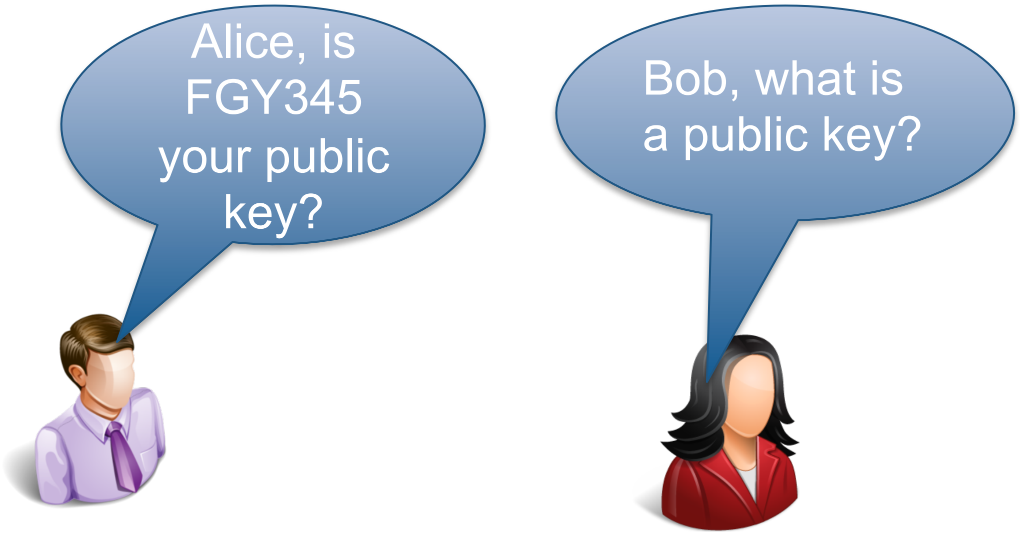
- How to learn and verify the other party’s key ?
- Trust-based access control

Trust establishment

- How to learn and verify the other party's key before establish a secure communication channel ?
  - Out of band trust establishment
  - Trust establishment by the provider

Out of band trust establishment

- Unintuitive, error-prone

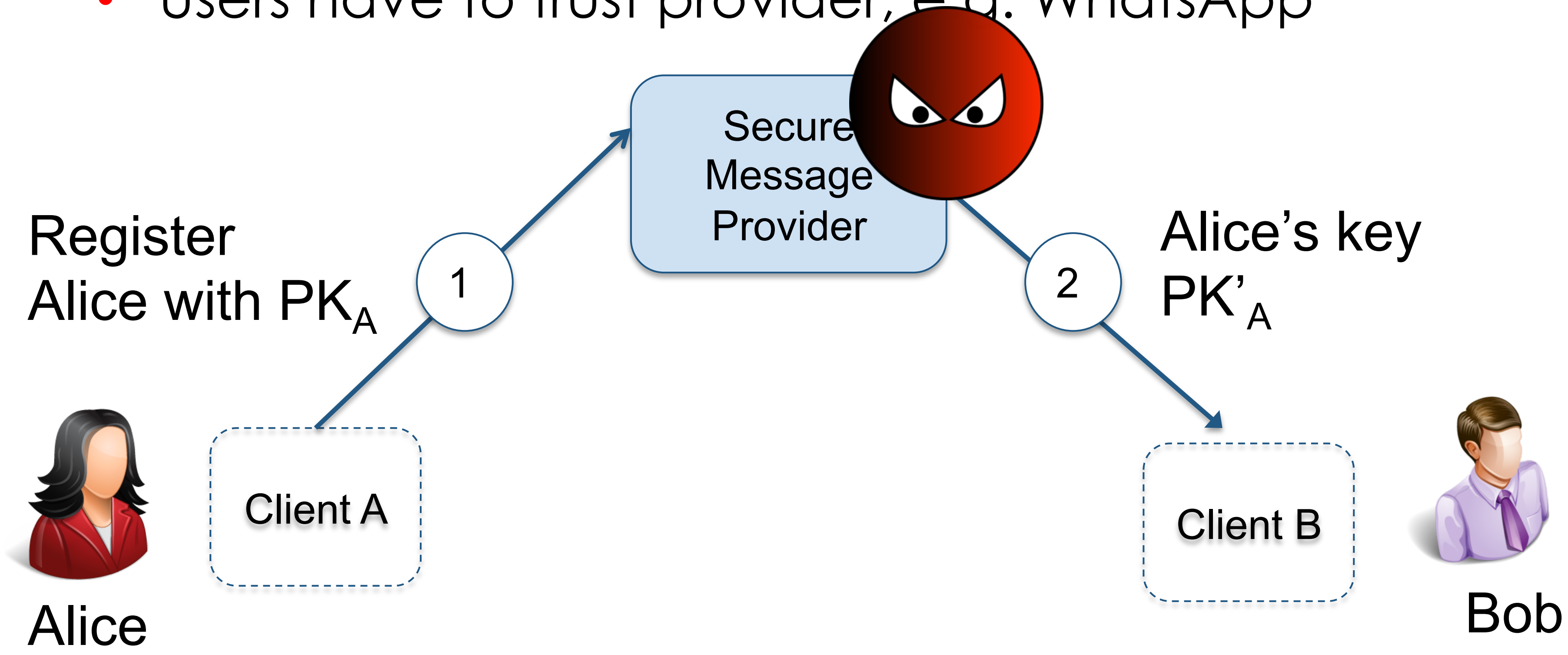


Bob

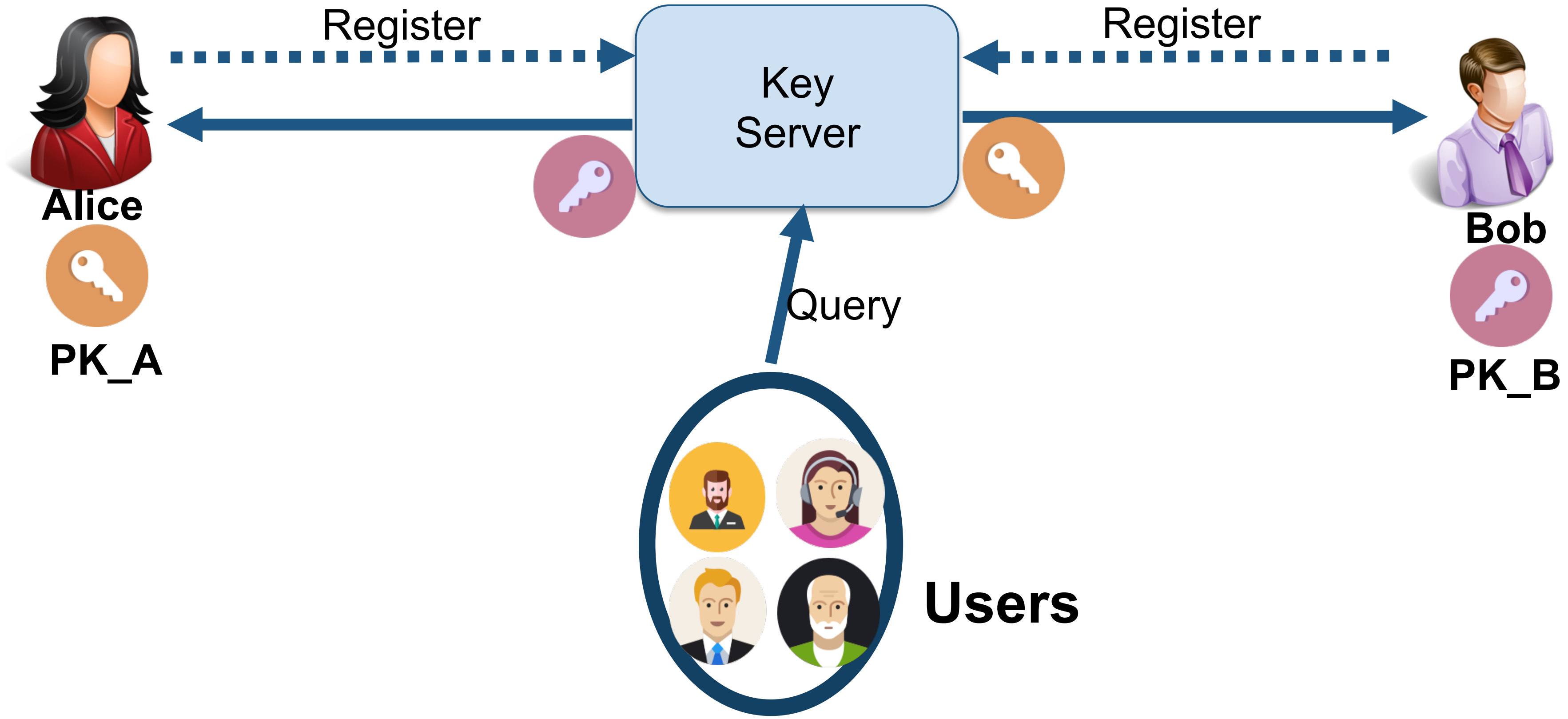
Alice

Trust establishment by the provider
Centralized key server

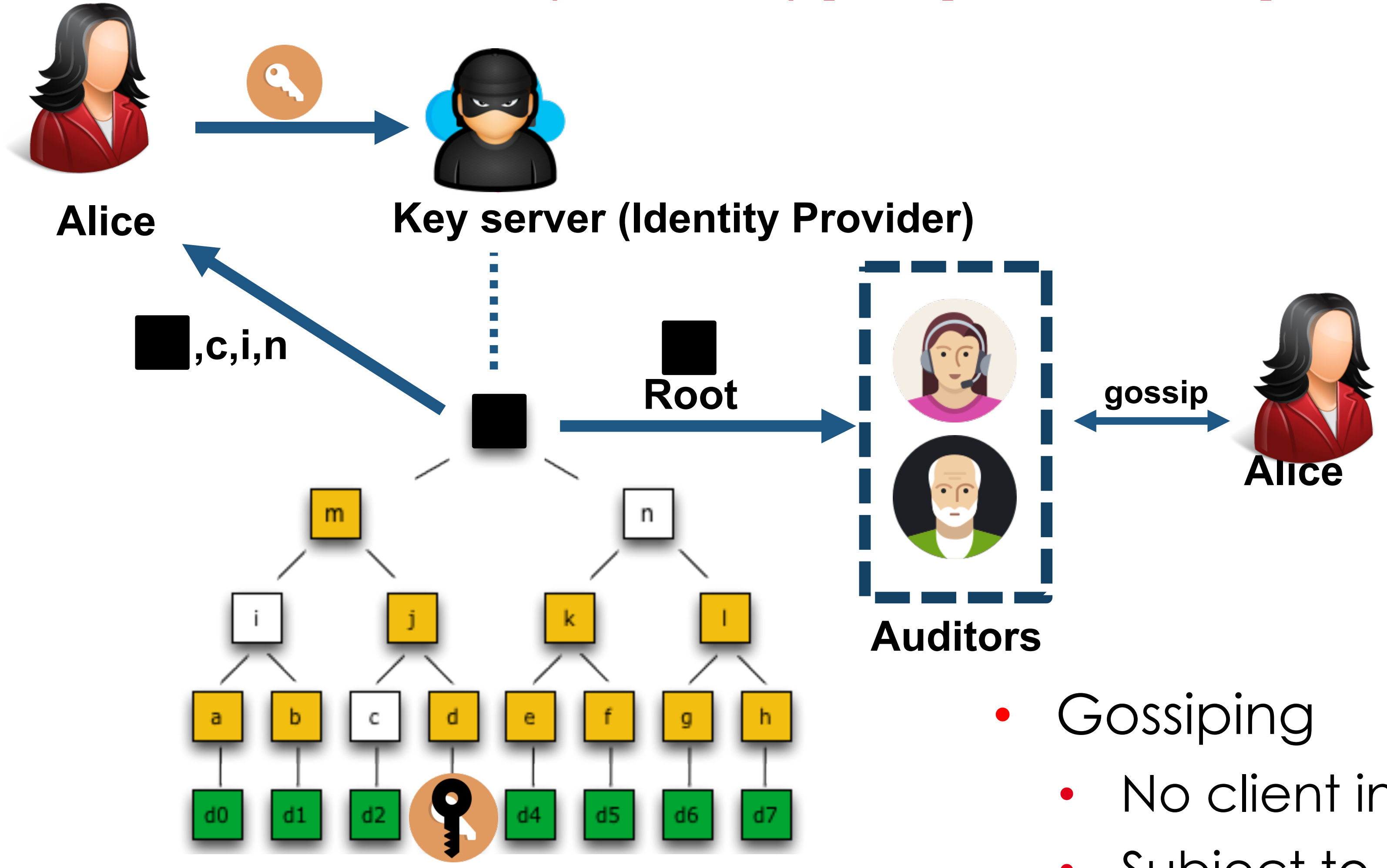
- Clients query providers for keys of other users
- Users have to trust provider, e.g. WhatsApp



Transparent log

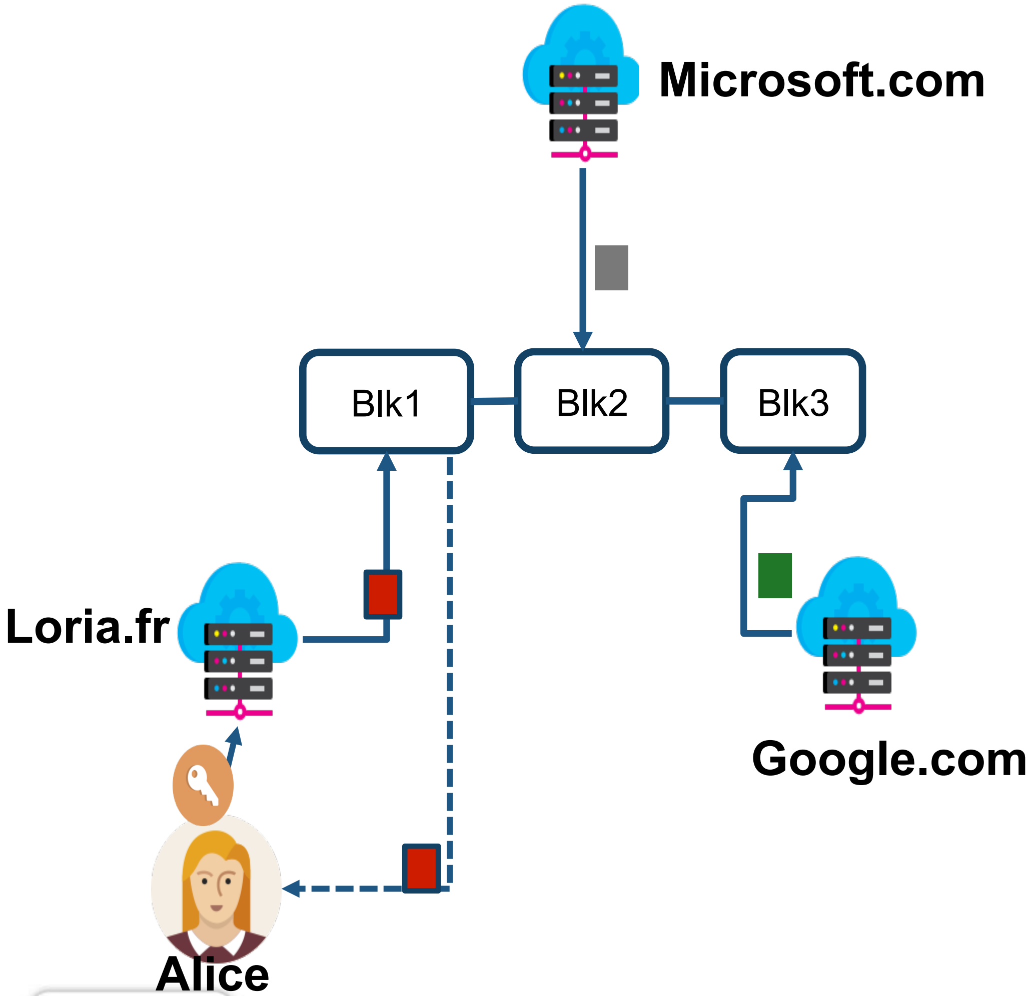


Certificate transparency[L14]/CONIKS [MBBFF15]



- Gossiping
  - No client incentive
  - Subject to Sybil and Eclipse attacks

Trusternity: Blockchain-based Auditing of Transparent Log Servers [NEIP18]

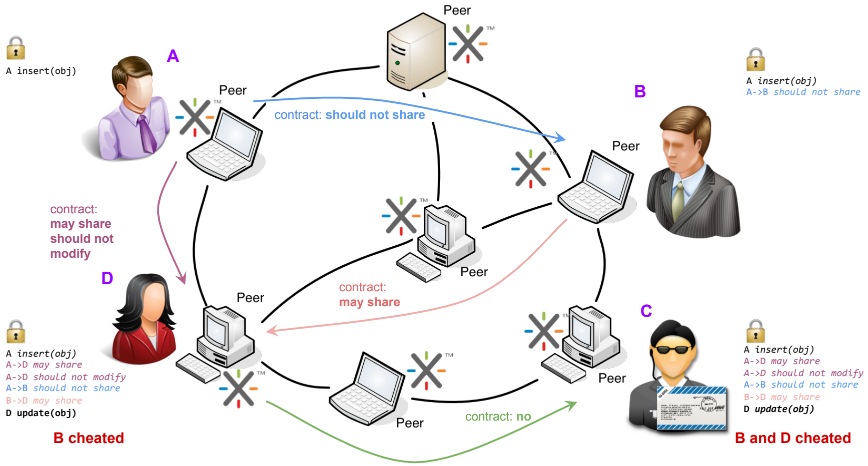


Trust-based access control

- Dynamic trust values among users
- *How to **define an access control based on trust** and how to **compute trust based on collaborative experience**?*

Trust computation

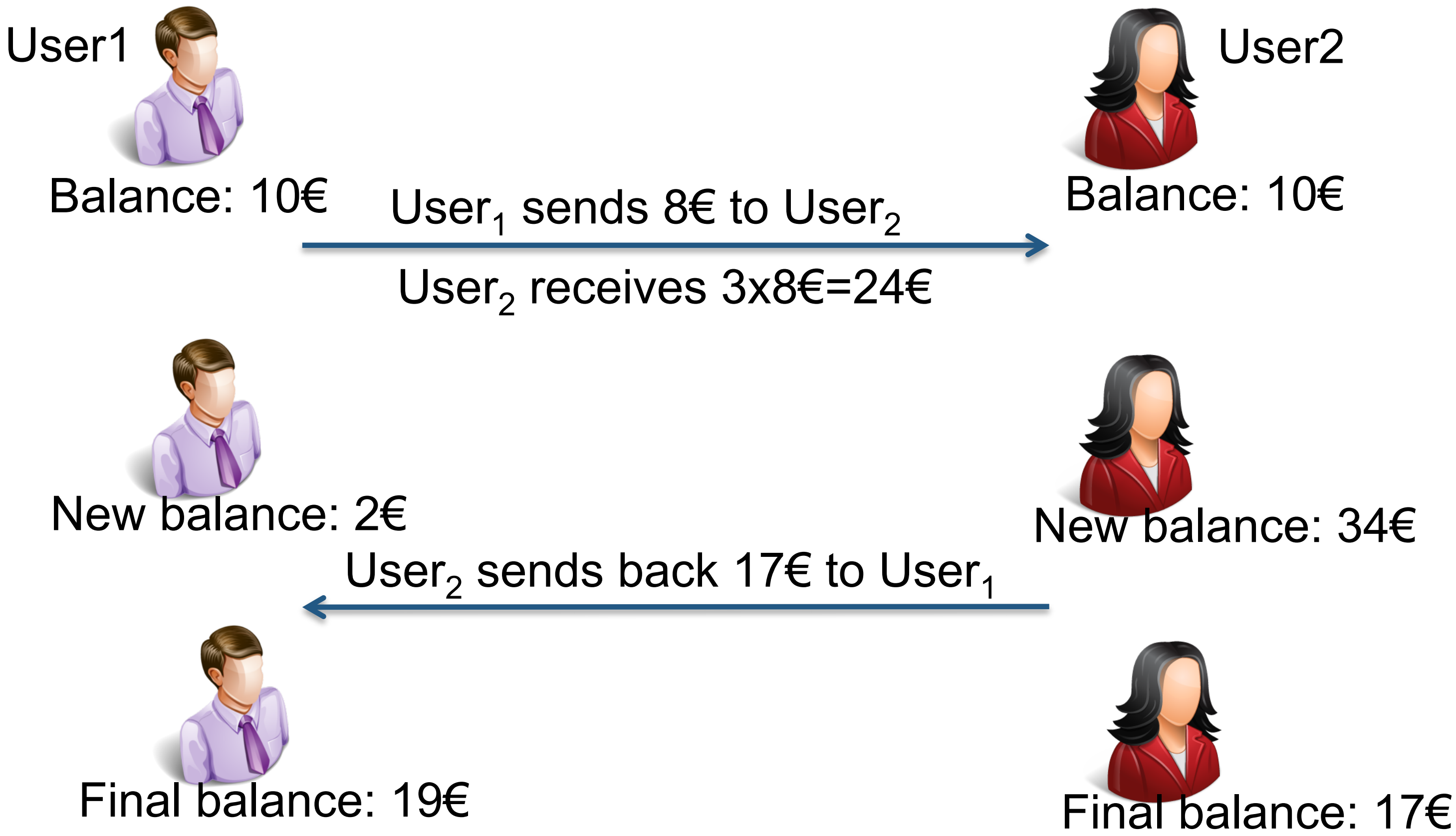
- Respect/Violation of contracts
  - Contracts in collaborative editing (share, edit)



- Reporting of fake news in Facebook
- Quality of user contributions

Validation of trust-based collaboration

- Using game theory (trust game) [BDM95]



Validation of trust-based collaboration

- Proposal of a trust metric reflecting user behavior [DI16]
- User studies on various trust game variations
  - Trust can replace knowing the identity of collaborators
  - People take into account the trust value of the partner in their future collaboration

Large-scale trustworthy distributed collaborative systems

- New uses and new practices due to large scale adoption
- New challenges
  - Consistency of replicated data
  - User studies
  - Trust and Security

References

- **[EGR91]** Groupware: Some issues and experiences, C.A. Ellis, S. J. Gibbs and G. Rein, Communications of the ACM,1991
- **[J88]** GroupWare: Computer Support for Business Teams. R. Johansen. The Free Press, New York, NY, USA, 1988.
- **[SG88]** Computer-based real-time conferencing systems. Sunil Sarin and Irene Greif. Morgan Kaufmann Publishers Inc., 1988, page 397–422.
- **[G90]** Sharing views and interactions with single-user applications. Saul Greenberg. ACM SIGOIS and IEEE CS TC-OA conference on Office information systems,1990.
- **[SFBKLS88]** Beyond the chalkboard: computer support for collaboration and problem solving in meetings. Mark Stefik, Gregg Foster, Daniel G. Bobrow, Kenneth Kahn, Stan Lanning, and Lucy Suchman. Morgan Kaufmann Publishers Inc., 1988, page 335–366

References

- **[EG89]** Concurrency Control in GroupWare Systems, C.A. Ellis and S.J. Gibbs. ACM SIGMOD Record 18(2), 1989.
- **[SS05]** Optimistic replication. Y. Saito and M. Shapiro. *ACM Computing Surveys*. 37(1), 2005.
- **[RNG96]** An integrating, transformation-oriented approach to concurrency control and undo in group editors, M. Ressel, D. Nitsche-Ruhland, and R. Gunzenhäuser. CSCW 1996.
- **[OUMI06]** Tombstone transformation functions for ensuring consistency in collaborative editing systems, G. Oster, P. Urso, P. Molli, and A. Imine. CollaborateCom 2006.
- **[SCF97]** Serialization of concurrent operations in a distributed collaborative environment, M. Suleiman, M. Cart, and J. Ferrié. GROUP 1997.

References

- **[VCFS00]** Copies convergence in a distributed real-time collaborative environment. N. Vidot, M. Cart, J. Ferrié, and M. Suleiman. CSCW 2000.
- **[NCDL95]** High-latency, low-bandwidth windowing in the Jupiter collaboration system, D. A. Nichols, P. Curtis, M. Dixon, and J. Lamping. UIST 1995.
- **[SPBZ11]** Conflict-free Replicated Data Types, M. Shapiro, N. Preguica, C. Baquero, M. Zawirski. Research Report, RR-7687, INRIA, 2011
- **[PMSL09]** A commutative replicated data type for cooperative editing, N. Preguica, M. Joan, M. Shapiro, and M. Letia. ICDCS 2009.
- **[WUM09]** Logoot : a Scalable Optimistic Replication Algorithm for Collaborative Editing on P2P Networks, S. Weiss, P. Urso and P. Molli. ICDCS 2009.

References

- **[AMOI13]** Supporting Adaptable Granularity of Changes for Massive Scale Collaborative Editing, L. André, S. Martin and G. Oster C.-L. Ignat. CollaborateCom 2013.
- **[ASB18]** Delta state replicated data types. Paulo Sérgio Almeida, Ali Shoker, Carlos Baquero. Journal of Parallel and Distributed Computing, 2018
- **[NEOIC17]** MUTE: A Peer-to-Peer Web-based Real-time Collaborative Editor. Matthieu Nicolas, Victorien Elvinger, Gérald Oster, Claudia-Lavinia Ignat, François Charoy. ECSCW, 2017
- **[DI16]** Performance of real-time collaborative editors at large scale: User perspective. Quang Vinh Dang, Claudia-Lavinia Ignat. Networking 2016

References

- **[IOFSC15]** How Do User Groups Cope with Delay in Real-Time Collaborative Note Taking. Claudia-Lavinia Ignat, Gérald Oster, Olivia Fox, Valerie L. Shalin, François Charoy. ECSCW 2015
- **[NI18]** An Analysis of Merge Conflicts and Resolutions in Git-Based Open Source Projects. Hoai Le Nguyen, Claudia-Lavinia Ignat. Journal of Computer Supported Cooperative Work, 2018
- **[MBBFF15]** CONIKS: Bringing key transparency to end users. M. Melara, A. Blankstein, J. Bonneau, E. W. Felten, M. J. Freedman. *USENIX Security*. 2015.
- **[L14]** Certificate transparency. B. Laurie. Queue 12(8), 2014
- **[NEIP18]** Blockchain-Based Auditing of Transparent Log Servers. Hoang-Long Nguyen, Jean-Philippe Eisenbarth, Claudia-Lavinia Ignat, Olivier Perrin. DBSec 2018

References

- **[BDM95]** Trust, social history, and reciprocity. J. Berg, J. Dickhaut, and K. McCabe, Games and Econ. Behav.1995.
- **[DI16]** Computational Trust Model for Repeated Trust Games. Quang Vinh Dang, Claudia-Lavinia Ignat. Trustcom 2016

Thank you

COAST Team

http://team.inria.fr/coast/