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CRDT-based Collaborative Editing in OppNets: a Practical Experiment

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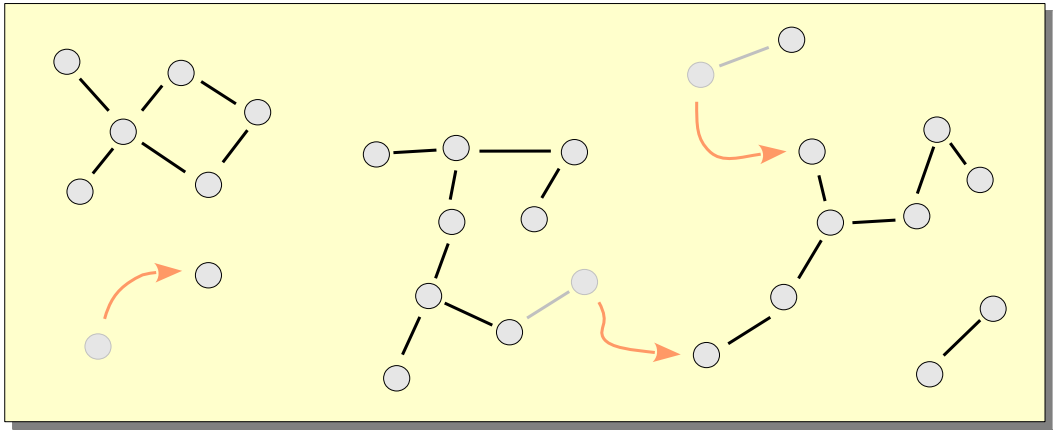
Opportunistic Networks (OppNets)

- Characteristics
  - Mobile nodes with often unpredictable mobility
  - Device-to-device communication (short-range radio)
  - Sparse and/or irregular spatial distribution of the nodes

- Challenge of network-wide communication
  - Absence of continuous end-to-end connectivity
  - Network partitioned in “islands” with fluctuating boundaries

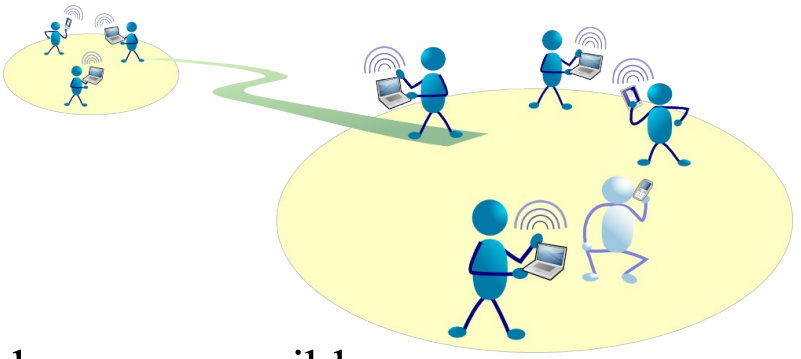


Opportunistic Networks (OppNets)

- Exploiting the mobility to communicate: the "store, carry, and forward" principle

  Each mobile node can...

  – store messages for a while
  – carry these messages while moving around
  – forward these messages to neighbor nodes whenever possible



- Main research activity in OppNets
  – Development of routing/forwarding algorithm
  – Hypotheses
    – Neeed for network-wide message passing (point-to-point or dissemination)
    – Need of message-oriented API

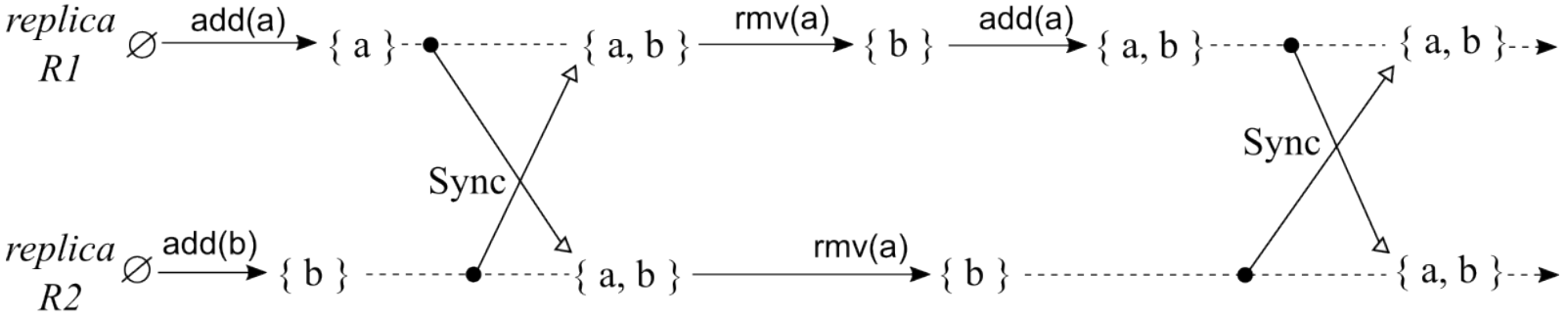
Yet, possible alternative based on shared data structures

Conflict-free Replicated DataTypes

- Target sharing of data structures in distributed environments
  - Support optimistic replication (eventual consistency)
  - Independent local updates + asynchronous synchronization

- Strong theoretical background for several data types (counters, registers, sets, maps, lists, graphs...)
  - Specific update operations
  - Concurrency semantics

- Example : Add-wins sets



Synchronization of CRDTs

- CRDTs typically deployed in Internet-based P2P or cloud-based networks
  - *Operation-based CRDTs*: broadcast each update to all other replicas (requires reliable broadcast)
  - *State-based CRDTs*: each replica periodically synchronizes with another randomly-selected replica

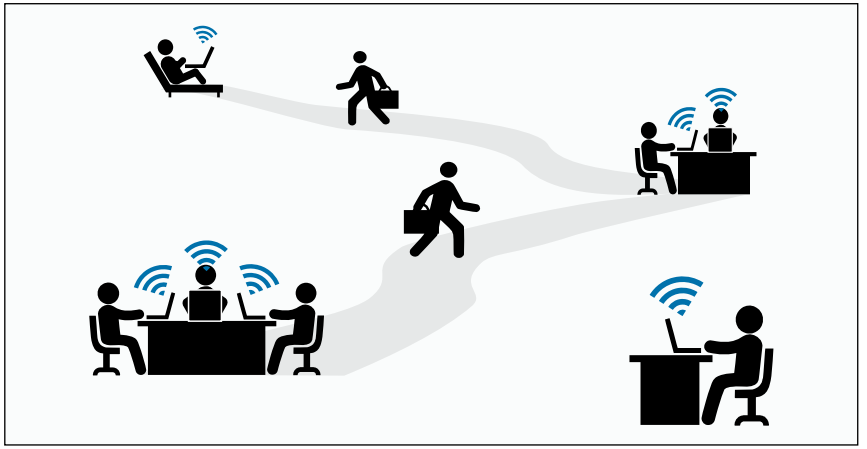
- Synchronization in OppNets studied in previous simulations
  - Operation-based: needs epidemic dissemination
    - too many small messages
  - State-based: synchronization with (temporary) neighbors
    - no routing required but large amount of data (full states) transmitted
  - A variant of state-based is the best compromise: delta-state-based synchro.
    - exchange of digests (typically state vectors) to determine the minimum amount of data to transmit

- Practical use of CRDTs in OppNets still to be demonstrated

Experimenting a CRDT-based application for OppNets

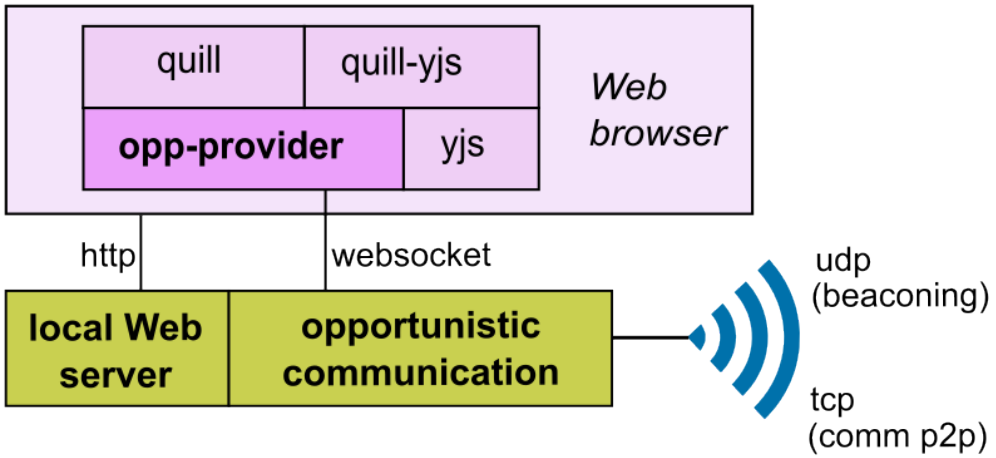
- Choice of application : collaborative edition of a document
  - Demanding application: respect of the causality of operations not trivial
  - Meaningful at small scale
  - Some of the needed buildings blocks already available

- Setting
  - Several contributors to a unique document, during several days
  - Laptops synchronize only when next to each other
    - via wireless D2D transmissions
  - The contributors move
    - their laptops are then switched off



Design and implementation

- Global architecture
  - Web-based application
  - Reuse of existing blocks
    - Text editor:
      Quill (HTML/CSS/Javascript)
    - Text CRDT implementation:
      Yjs (Javascript)
  - Development of dedicated software
    - Opportunistic communication layer
    - Yjs provider dedicated to OppNets



Design and implementation

- Opportunistic communication
  - Neighbor discovery
    - UDP Multicast
  - Synchronization (between two neighbors)
    - TCP session with TLS encryption

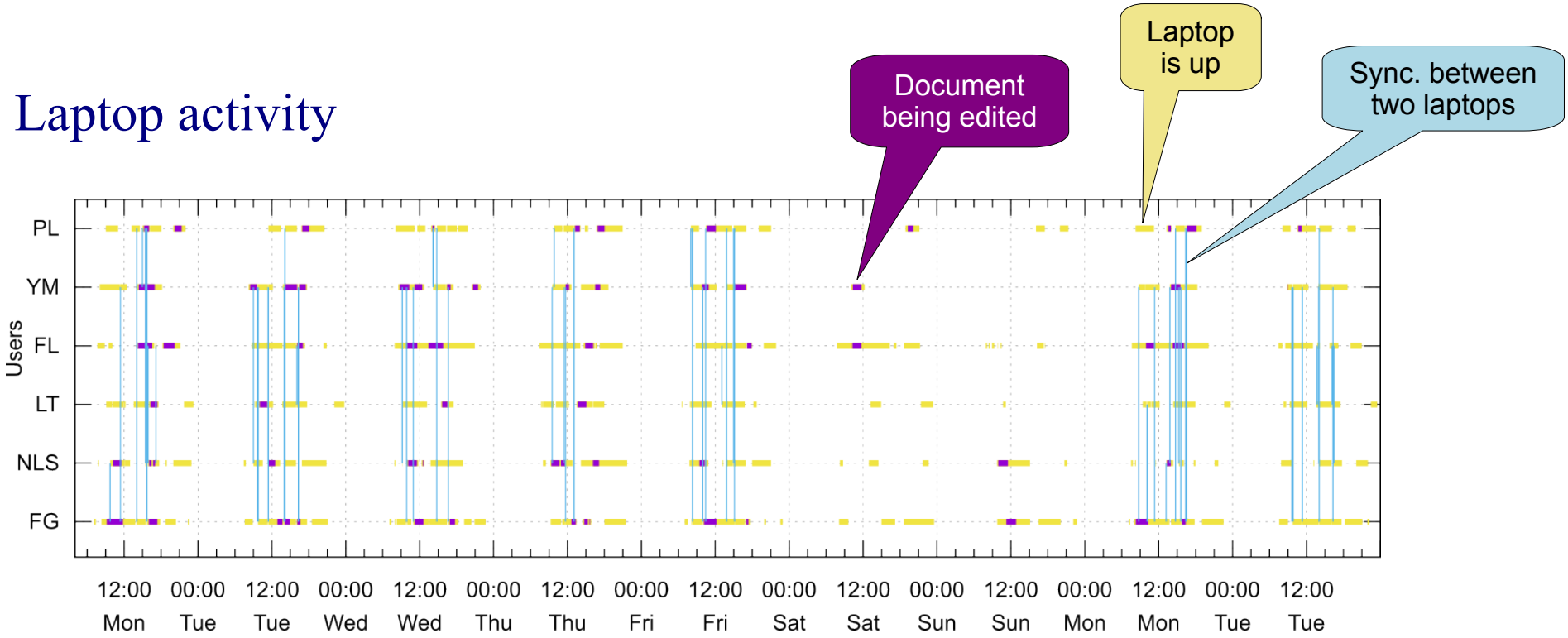
- Yjs provider dedicated to OppNets (opp-provider)
  - Ensures CRDT synchronization
    - When a user modifies the text: broadcast of the update
    - When two neighbors get in contact: delta-state synchronization
      - exchange of state vectors + exchange of delta states

Experiment

- Collaborative editing of a research report
  - 9 days
  - 6 contributors identified by their initials (PL, YM, FL, LT, NLS, FG)
- Laptop configuration
  - Wi-Fi dongle dedicated to the experiment
  - Systemd service for the opportunistic commuication layer
  - Web browser with local server for Quill editor/Yjs CRDT/opp-provider
  - Log for collecting results

Results: activity

- Laptop activity

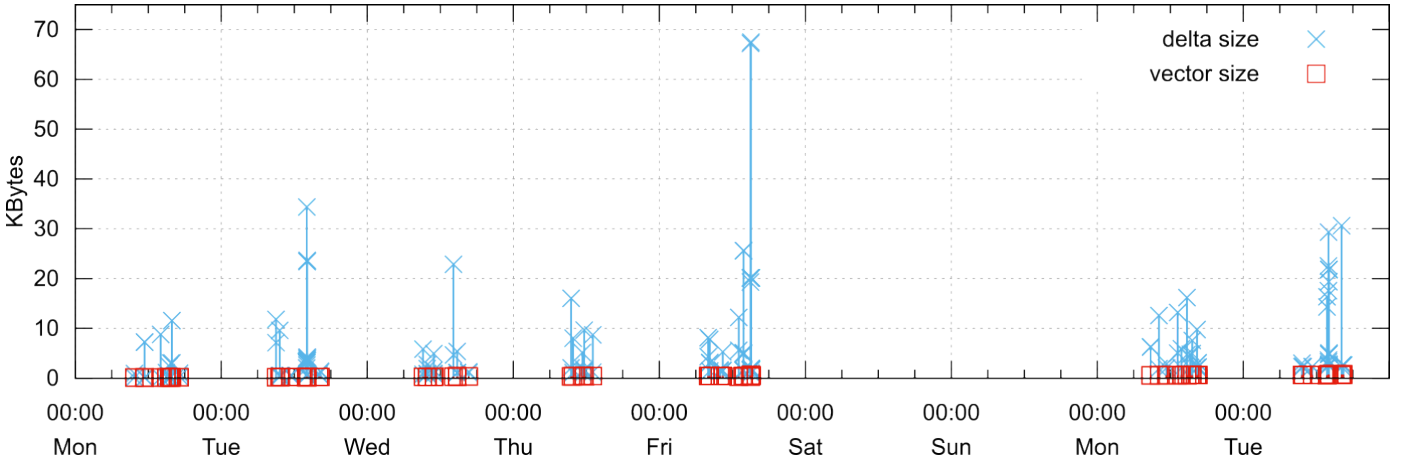


- Editing stats

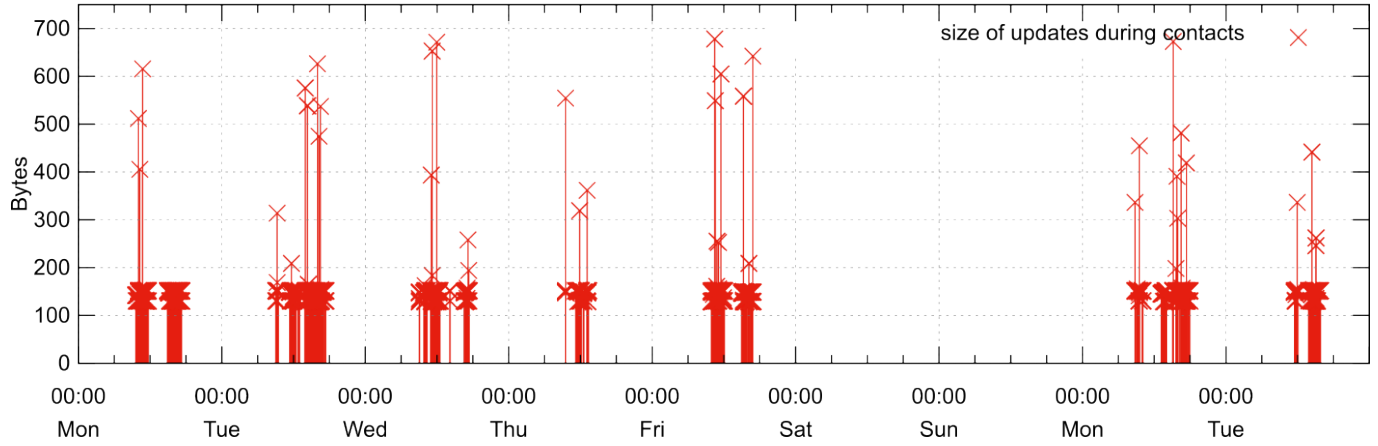
Size of the final document	102 651 characters (36 pages)
Nb. of editing events	114 612 “ins”, 6 821 “del”, 104 “cut”, 81 “paste”
Nb. of synchronizations upon radio contact	109
Nb. of updates transferred during radio contacts	102 561

Results: synchronization

- Size of the messages carrying state vectors and delta-states

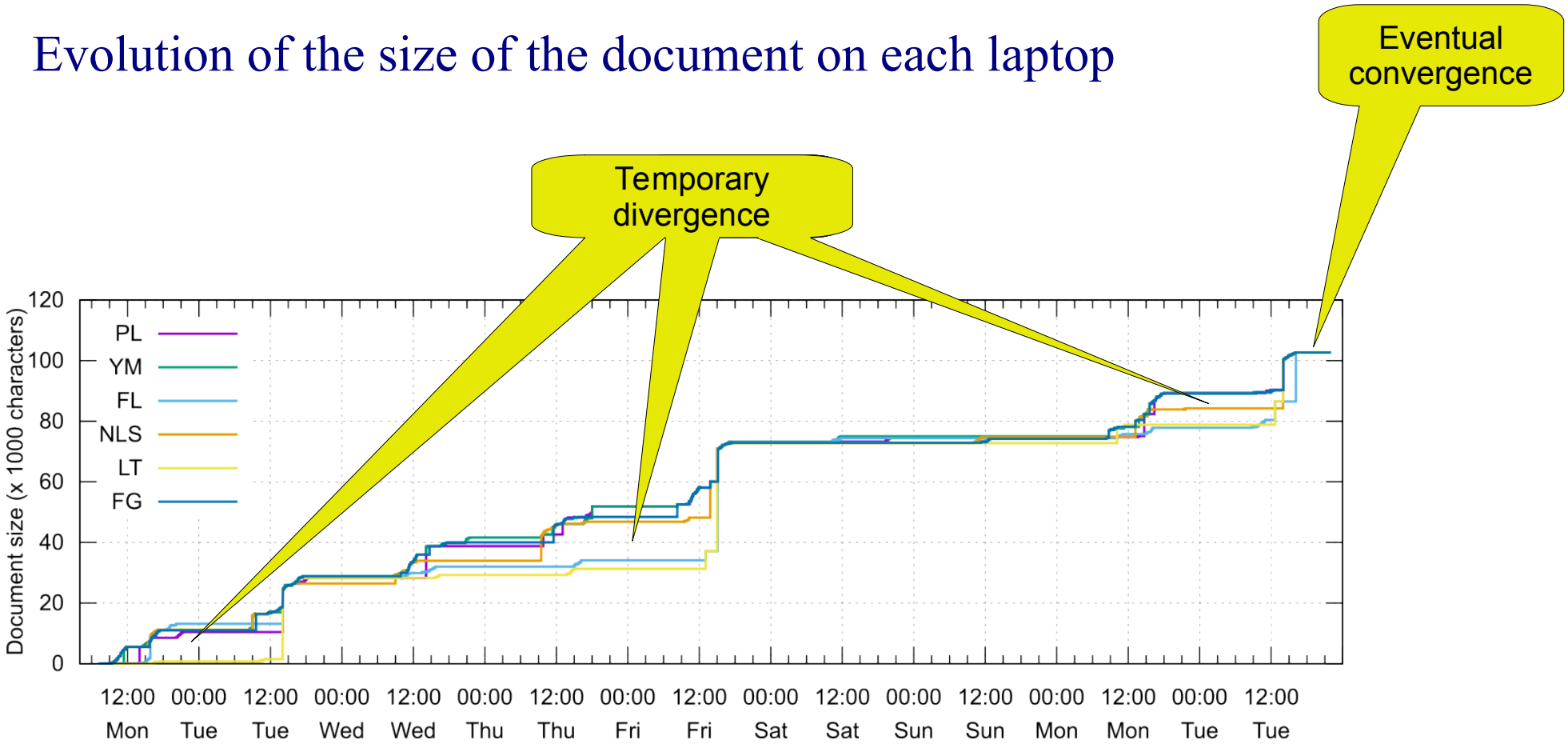


- Size of update messages



Results: convergence

- Evolution of the size of the document on each laptop



Conclusion

- Original real-life experiment of collaborative editing based on CRDT on an OppNet
  - Off-the-shelf text editor + CRDT implementation
  - Dedicated software for the synchronization of replicas
- Main outcome of the experiment: demonstration of the feasibility of the approach
  - Realistic conditions (mobility + editing actions)
  - Final convergence / bearable temporary divergences
- In OppNets, the use of CRDT can be a good alternative to network-wide message routing
  - Higher level of programming abstraction for developers