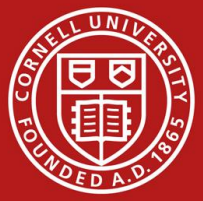

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Entangled Transactions

Nitin Gupta, Milos Nikolic, Sudip Roy, Gabriel Bender,
Lucja Kot, Johannes Gehrke, Christoph Koch

Coordination

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In the age of Web 2.0, users increasingly coordinate on data-driven tasks

Example: travel planning

- Mickey and Minnie want to travel to Seattle on the same flight

Coordination: Course Enrollment

Cornell University

Students want to enroll in classes with their friends

Interesting scenarios:

- Negative constraints
  - avoid the section my ex is in
- Strong mutual dependencies
  - I will take this tough class only if my friend takes it too

Coordination: MMOs

Cornell University

Players want alliances based on shared or complementary goals

- I will attack from the North if someone else attacks from the South

Alliances often formed with strangers for the purpose of achieving one goal

Coordination: SIGMOD 2011

Room Sharing among attendees of the 2011 ACM SIGMOD Conference

The conference officers have set up a web page where interested attendees of the conference can register their interest in sharing rooms at the conference hotel. Through this service attendees can enter their details so that interested people can contact each other.

To register your interest, please submit your information at: http://bit.ly/sigm_share_room (URL shortener service forwarding to a Google Spreadsheets form). This service is provided solely as a convenience to participants that seek to share accommodation costs. Please contact directly participants that have expressed interest. The organizers will not be involved in the process nor are they responsible for possible abuse of the information you provide.

Coordination: SIGMOD 2011

Cornell University

https://spreadsheets.google.com/spreadsheet/viewform?formkey=dEVscThIZkVJMkdJeUFCX1pSZVFPUXc6MQ

Sharing a room at the Conference Hotel?

This form allows people who want to stay at the conference hotel to express their interest in sharing rooms.
Please fill out the following form, all people expressing interest in sharing a room can then contact each other by looking at the
following page http://bit.ly/sigm_share_room_list

* Required

Name *

email *

Period you wish to stay at the hotel *

Please add any constraints on sharing a room (gender, etc)

Submit

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Coordination: SIGMOD 2011

Cornell University

https://spreadsheets.google.com/spreadsheet/pub?hl=en&hl=en&key=0A

Sharing a room at the Conference Hotel? : List

Timestamp	Name	email	Period you wish to stay at the hotel	Please add any constraints on sharing a room (gender, etc)
5/10/2011 6:15:25	[redacted]	[redacted]	12/06/2011-16/06/2011	Female
5/10/2011 6:38:39	[redacted]	[redacted]	June 13 - June 17 (4 nights)	I will be interested to share a room (only females) during the conference. thanks!
5/10/2011 16:38:58	[redacted]	[redacted]	12-17 June	Males only. I already have a room reservation -- looking to fill the other bed and split the cost.
5/10/2011 18:34:49	[redacted]	[redacted]	5 nights June 12-16 (inclusive)	
5/12/2011 13:03:30	[redacted]	[redacted]	13th-16th June	prefer females (i'm a girl)
5/13/2011 12:45:54	[redacted]	[redacted]	12-17 June	
5/14/2011 12:20:15	[redacted]	[redacted]	Check-in 11 , Check-out 15	n/a I'm easy going :)
5/23/2011 22:47:20	[redacted]	[redacted]	12th-17th	
5/25/2011 23:16:36	[redacted]	[redacted]	June 12 - June 17	male
6/4/2011 13:10:08	[redacted]	[redacted]	June 12th	Gender: male

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Entangled Transactions

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Mickey expresses his intention to coordinate

- "I want to travel to Seattle on the same flight as Minnie"

Minnie expresses a symmetric intention

System takes care of the rest

To make this a reality, need:

- a basic primitive for coordination – entangled queries (SIGMOD 2011)
- an understanding of how entangled queries fit into transactions (this paper)

Entangled Queries

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```
SELECT 'Mickey', Flightno        INTO ANSWER Booking
WHERE
('Minnie', Flightno)             IN  ANSWER Booking
AND Flightno                     IN  SELECT Flightno FROM Flights F
                                     WHERE F.Destination='Seattle'
CHOOSE 1
```

- ANSWER Booking is an ephemeral relation
- exists only when the queries are answered
- used to collect the answers to all "participating" queries
- allows the expression of cross-constraints beetween answers

Entangled Queries

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```
SELECT 'Mickey', Flightno        INTO ANSWER Booking
WHERE
('Minnie', Flightno)             IN  ANSWER Booking
AND Flightno                     IN  SELECT Flightno FROM Flights F
                                     WHERE F.Destination='Seattle'
CHOOSE 1
```

```
SELECT 'Minnie', Flightno        INTO ANSWER Booking
WHERE
('Mickey', Flightno)             IN  ANSWER Booking
AND Flightno                     IN  SELECT F.Flightno FROM Flights F, Airlines A
                                     WHERE F.Destination='Seattle'
                                     AND F.Flightno = A.Flightno
                                     AND A.Airline = 'United'
CHOOSE 1
```

Evaluation Example

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Flight

Flightno	Destination
CO83	Seattle
CO82	Paris
UA211	Seattle
TH244	Chicago
UA112	Seattle

Airlines

Flightno	Airline
CO83	Continental
CO82	Continental
UA211	United
TH244	Thai
UA112	United

UA211 and UA112 satisfy all constraints

	Mickey's query	Minnie's query
Answer	(Mickey, UA112)	(Minnie, UA112)
Constraint	(Minnie, UA112)	(Mickey, UA112)

Entangled Transactions

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Entangled queries typically embedded in transactions

1. coordinate on flight number
2. book ticket based on result from step 1
3. commit

More interesting scenario:

1. coordinate on flight number
2. book ticket
3. coordinate on hotel based on date of flight chosen
4. book hotel
5. commit

Mickey's Entangled Transaction

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BEGIN TRANSACTION;

SELECT `Mickey', fno, fdate AS @ArrivalDay INTO ANSWER FlightRes
WHERE fno, date IN (SELECT fno, fdate FROM Flights WHERE dest=`Seattle')
AND (`Minnie', fno, fdate) IN ANSWER FlightRes
CHOOSE 1;

-- (Code to perform flight booking omitted)

SELECT `Mickey', hid, @ArrivalDay, `2011-09-02' INTO ANSWER HotelRes
WHERE hid IN (SELECT hid FROM Hotels WHERE location=`Seattle')
AND (`Minnie', hid, @ArrivalDay, `2011-09-02') IN ANSWER HotelRes
CHOOSE 1;

-- (Code to perform hotel booking omitted)

COMMIT;

Research Challenges

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What kind of “transaction” is this?

- a classical transaction is a standalone, coherent unit of work
- an entangled transaction is not standalone – requires an entanglement partner!

What happens to isolation?

- there is communication, so classical isolation is broken
- but some sort of “residual isolation” is desirable

Need a formal semantic model for entangled transactions

Research Challenges

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How do we actually run entangled transactions?

- how do we enforce "correct" execution as defined in semantic model?
  - locking, optimistic cc?
- what if something goes wrong?
  - Minnie never submits her matching transaction
  - an entangled query fails
  - entanglement succeeds, but *then* one of the transactions aborts

Need an execution model for entangled transactions

- one size will likely not fit all

Research Challenges

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How do we run entangled transactions in a real system?

- is entangled transaction support implemented in the middle tier or within the DBMS?
- what is the overall system architecture?
- how do we make this fast and scalable?

Our Contributions

Cornell University

A semantic model for entangled transactions

- formalizes the entangled equivalents of the ACID properties

A practical execution model

- suitable for realistic scenarios like travel planning
- (ongoing research)

A concrete system design and prototype implementation

- middle-tier support for entangled transactions
- integrates with existing DBMS functionality

Experimental evaluation

Our Contributions

Cornell University

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A concrete system design and prototype implementation

- middle-tier support for entangled transactions
- integrates with existing DBMS functionality

Experimental evaluation

Semantic Model - Consistency

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What is a transaction?

- a standalone, coherent unit of work

Formalized in the *consistency* assumption

Every transaction, if executed on an initially consistent database by itself , will produce another consistent database.

Semantic Model - Consistency

Cornell University

What is an entangled transaction?

- a standalone, coherent unit of work modulo its need for entangled query answers

Formalized in the *oracle-consistency* assumption

- an entangled query oracle is a process that (only) answers entangled queries

Every entangled transaction, if executed on an initially consistent database by itself except for an entangled query oracle that returns valid query answers, will produce another consistent database.

Semantic Model - Isolation

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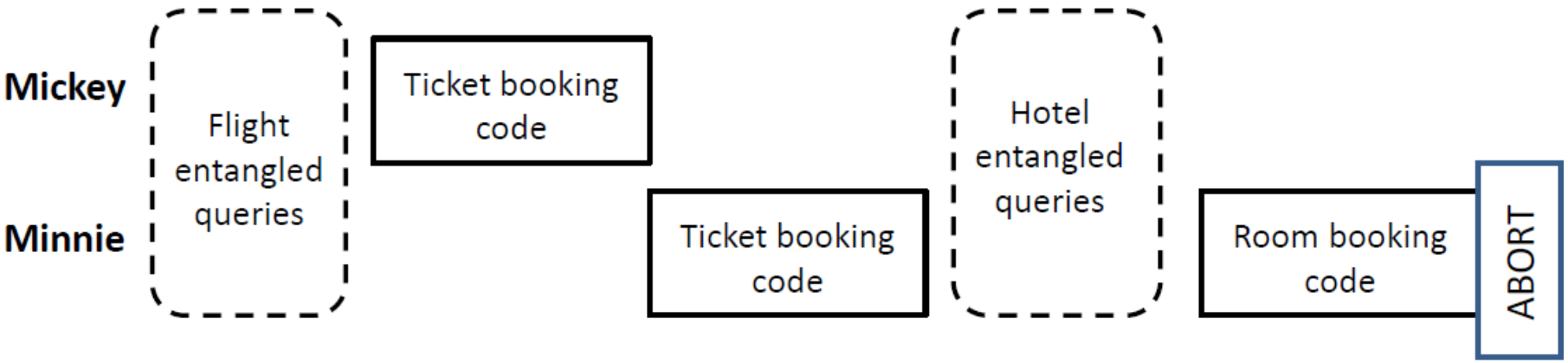
Classically, two ways to formalize isolation:

- exclusion of anomalies (dirty reads etc.)
- serializability – equivalence to a serial schedule
- results that link the two notions

Challenges in the entangled case:

- serializability no longer makes sense
- new isolation anomalies unique to entangled setting

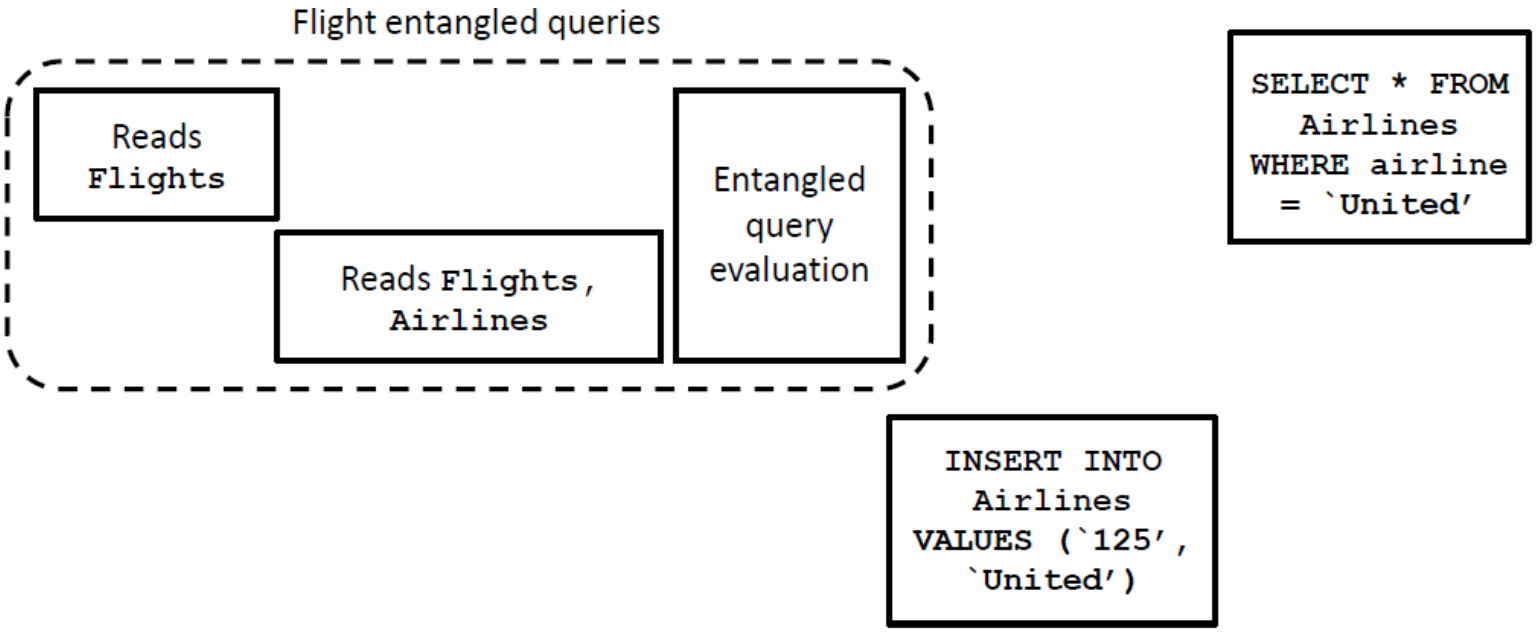
New Isolation Anomaly #1



Widowed transaction

- what if one transaction aborts?
- entanglement is a kind of dirty read (on the system state)

New Isolation Anomaly #2



Unrepeatable quasi-read

- information flows through entanglement to a transaction, even if it does not read a table directly

Semantic Model - Isolation

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Two definitions of isolation for an entangled schedule:

- anomaly-based entangled isolation
  - exclude all the classical anomalies plus widowed transactions and unrepeatable quasi-reads
- oracle-serializability
  - (final state) equivalence to schedule where the same transactions execute serially along a suitable oracle

Theorem: Anomaly-based entangled isolation implies oracle-serializability

- so list of anomalies is “complete”
- see paper for details!

Semantic Model Summary

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Consistency

- a transaction executing on its own with an oracle takes DB from one consistent state to another

Isolation

- anomaly-based and oracle-serializability definitions
- Theorem: the former implies the latter

Atomicity

- transaction must complete or be rolled back

Durability

- if a transaction commits, changes must persist

Experimental Evaluation

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We ran several experiments using our prototype

- implemented in Java
- uses JDBC to connect to a MySQL database system (InnoDB)

Experiments investigate:

- the overhead of providing transactional guarantees
  - "How much slower is the running time if we enclose the code in BEGIN TRANSACTION; and COMMIT; ?"
- the performance impact of different workloads (transactions match well or badly, in a simple or complex way)
- what happens when we vary parameters in our execution model

Transactional Overhead

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Three workload types

- NoSocial – a user books a flight
- Social – a user books a flight based on a friend's booking
- Entangled – a user coordinates with a friend to book a flight using entangled query

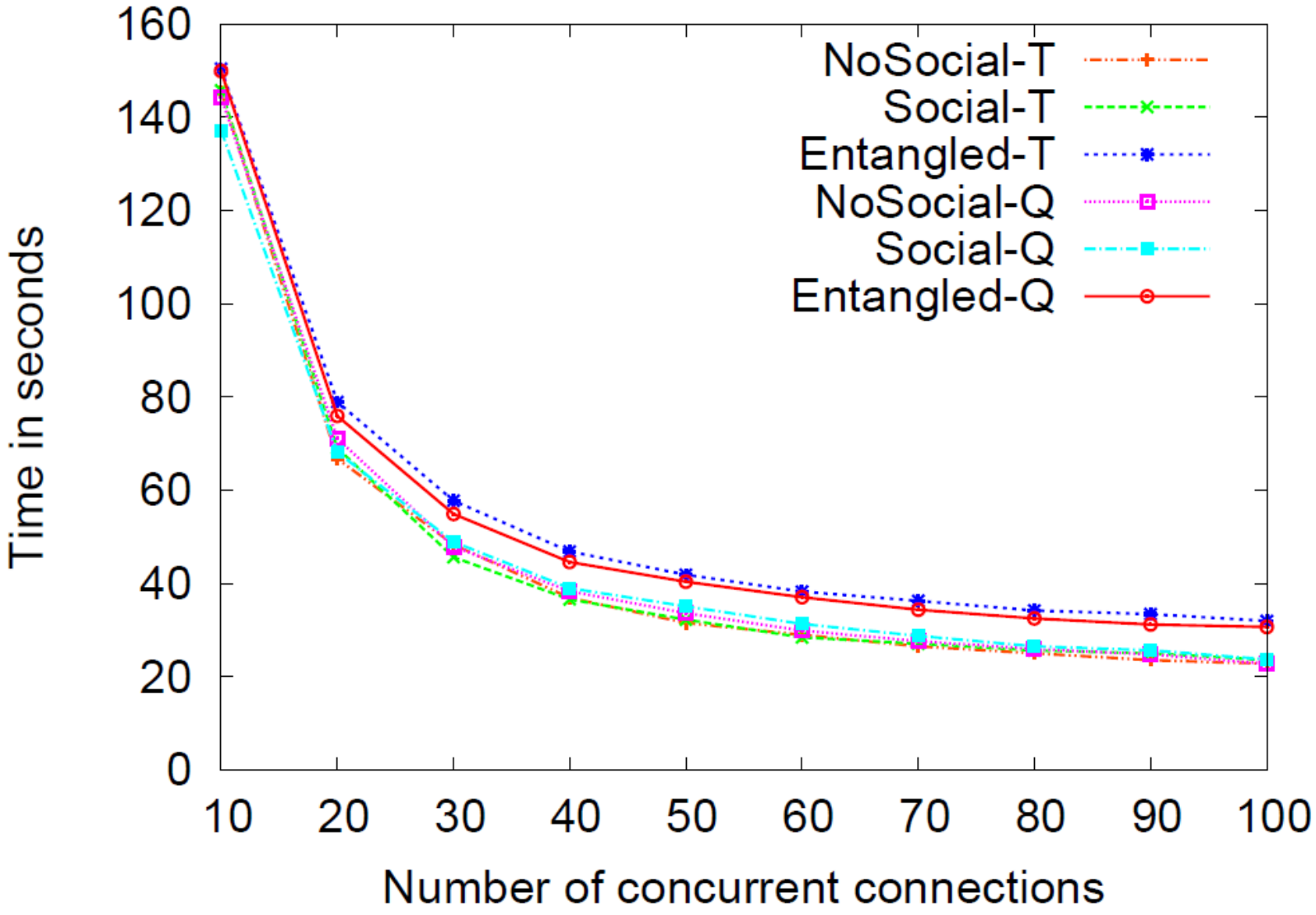
For each of these, generate a non-transactional (-Q) and a transactional (-T) workload

- 10000 transactions generated using Slashdot social network data

Determine running time for each workload

- this is a function of the number of concurrent connections

Results (10K-transaction Workloads)



Conclusion

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Entangled transactions are a powerful, clean and declarative way to support data-driven coordination

- formal semantic model with analogues of the classic ACID properties
- end-to-end solution with a practical execution model and an implemented prototype

Many exciting challenges for future work

- more execution models
- language and model extensions
- privacy issues
- ...

Additional Slides

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Run-based Execution Model

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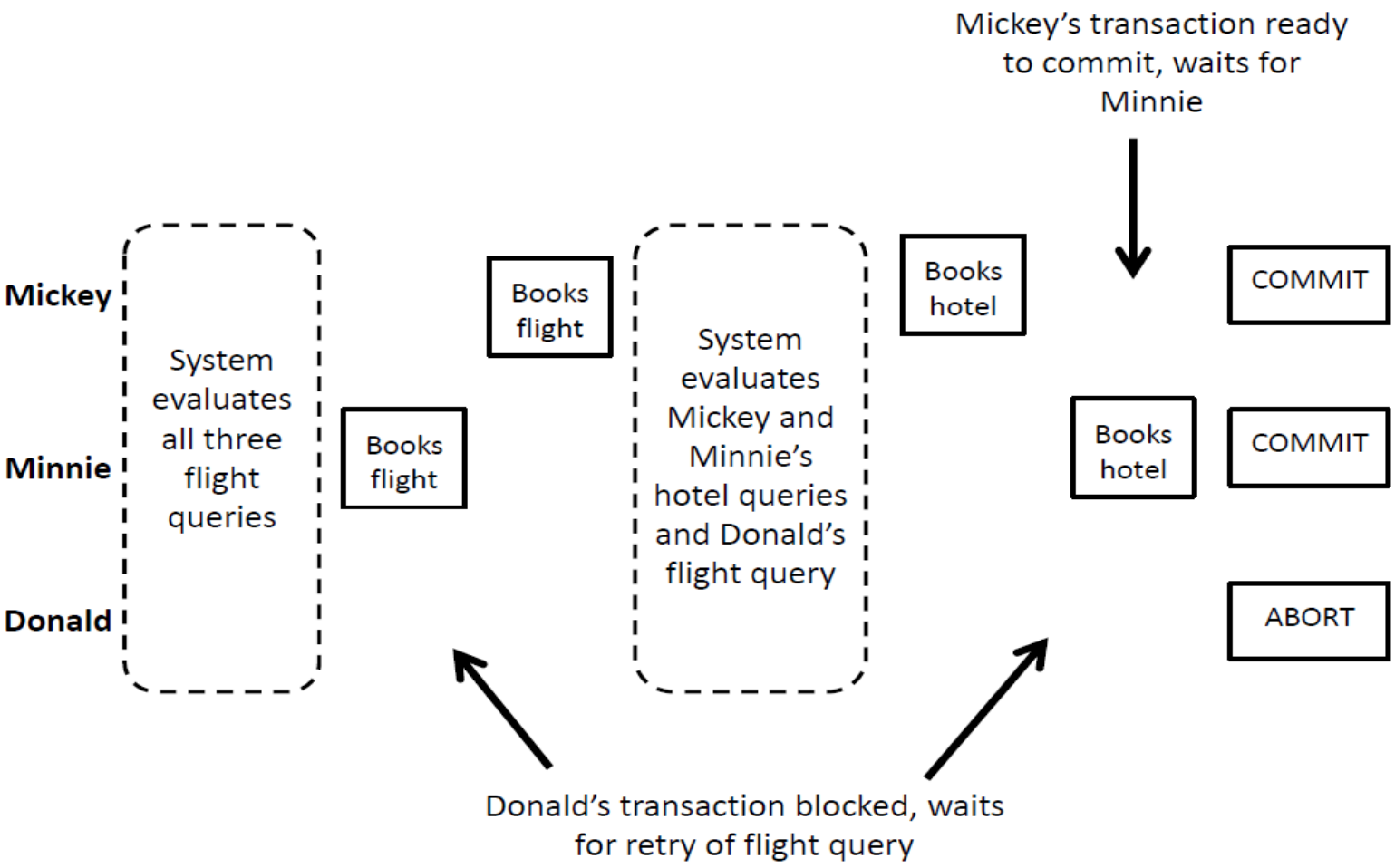
A simple execution for noninteractive transactions

Isolation achieved with appropriate locking and group commit requirement

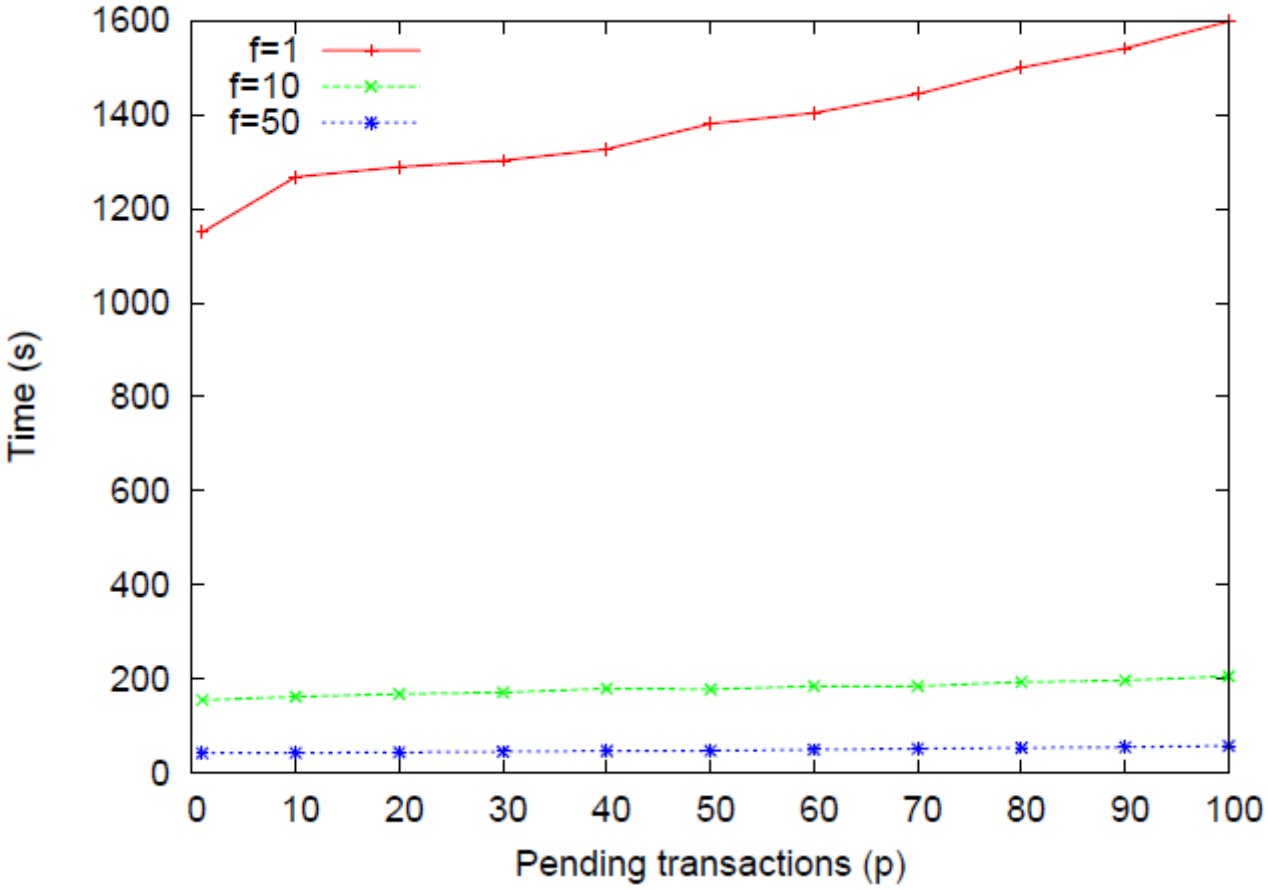
Run-based scheduling:

- transactions scheduled in batches or runs
- entangled queries are blocking points in evaluation
- run ends when every transaction is either ready to commit or blocked waiting for a partner

Transactions in a Run



Results: Pending Transactions



Results: Coordinating Set