Scalability

definition, assumptions and trade-offs

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TripCom at Web Scale

- The Web is *distributed*, *heterogeneous*, *dynamic*, and *open*.
- Required is a Triple Space platform which copes with these principles at Web scale.
- Classical guarantees encountered in closed environments cannot longer hold (per se).
- Adaptation of the *functional properties* publish and retrieve is required.
- Feasible *non-functional guarantees* must be determined from a scalability perspective

Outline

1. Scalability Deliverable
2. Scalability in TripCom
3. Recapitulation of non-functional / functional trade-offs
4. Configurations
   1. What is a configuration?
   2. How to define a configuration – some ideas!??

Scalability Deliverable

Sixth Framework Programme Priority 2
Information Society Technologies (IST)
Specific Targeted Research Project

Scalability Deliverable

- First Final Draft: 31.1.2008
  - We need to know what there will be
  - We need to know what there will not be
  - Remember:
    - First final release submitted to EC by April'08
    - Internal deadline thus mid-March!
- Entirely missing so far
  - Chapter 4 (FUB, but also CEFRIEL, ONTO, NUIG)
  - Chapter 5 (WP4, 8a, and 8b)
- Evaluation Results (Chapter 6.2)
  - As soon as possible!!! The sooner the better...
  - Satisfiability of Section 6.1

PM for Scalability Task

- Total PM: 24
  - 2nd year (M13-M24): 14
  - 3rd year (M25-M36: 10

- PM per Partner:
  - TUW 5
  - UIBK 4
  - **FUB 4**
  - **USTUTT 4**
  - **ONTO 2**
  - NUIG 2
  - CEFRIEL 2
  - Telefonica 1

New TOC

- chapter 1 Introduction
  - based on former chapter 3.1 (*The Scalability Task*)
- chapter 2 Scalability in TripCom
  - extended chapter 3.2 (*Definition*), additional arguments from the omitted chapter 2 (*Scalability in General*)
- chapter 3 Scalability Factors
  - former chapter 3.3/3.4 (*Scalability Factors/Assumptions&Trade-Offs*)
- chapter 4 Scalability Configurations
  - former chapter 3.5 (*Levels of Scalability*)
- chapter 5-8
  - former chapter 4-7

Scalability Deliverable

- 1 Introduction (UIBK, 31.01.2008)
- 2 Scalability in TripCom (NUIG/TUW, 15.09.2007)
- 3. Scalability Factors (UIBK, 15.09.2007)
  - 3.1 The Functional Aspects
  - 3.2 The Non-Functional Aspects
  - 3.3 Assumptions and Trade-Offs
- 4 Scalability Configurations (UIBK, 30.09.2007)
- 5 A Scalable Triple Space
  - 5.1 Triple Space Architecture (FUB/NUIG, 31.01.2008)
  - 5.2 Triple Space Conceptual Model (FUB, 31.01.2008)
  - 5.3 Triple Space Security (CEFRIEL, 31.01.2008)
  - 5.4 Triple Space Persistent Storage (ONTO, 31.01.2008)
- 6 Realization of Use Cases through Triple Space
  - 6.1 Semantic Web Services (USTUTT/UIBK, 31.01.2008)
  - 6.2 eHealth (CEFRIEL, 31.01.2008)
  - 6.3 EAI (Telefonica, 31.01.2008)
- 7 Evaluation of the Prototype
  - 7.1 Evaluation Procedure (TUW, 30.11.2007)
  - 7.2 Evaluation Results
  - 7.3 Discussion
- 8 Conclusions (USTUTT, 31.01.2008)

Scalability in TripCom

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Definition

- The performance of a scalable tuplespace network would increase gracefully as additional spaces, kernels and users are added (assuming that additional resources are added as needed).

- Scalability measures would include data access time (latency) for the operations of TripCom, frequency and parallelism of such requests, database size, number of spaces, number of kernels over which a space is distributed, number of users, and the number of internal messages generated to route a request from a TripCom entry point to a kernel which hosts the required subspace.

- If one of these measures is increased while most of the rest are held fixed, the other(s) should increase in a graceful way.

Scalability Rules of Thumb

- Some example scalability rules of thumb for TripCom follow:
  - TripCom data transmission time should scale no worse than linearly with respect to message size: O(m). We do not intend to implement adaptive data compression schemes which could yield sublinear scaling.
  - The data access time should be highly scalable with respect to the number of kernels in the network: O(log n), although the number of kernels need only scale linearly with respect to the number of spaces: O(n).

Consequence

- Scalability of Triple Space
- NOT scalability of a TS kernel and its components
  - Are considered cheap operations
  - Are thus neglected in this discussion

Scalability Models

- However, scalability models in TripCom
  - are more complicated than P2P models
  - demand more complex analysis and modeling methodologies than simulation
  - SIMULATIONS ARE IMPORTANT, AND MUST BE DONE AS SOON AS POSSIBLE
- What does it mean to have 10, 100 or 1000 spaces?
- What do we expect from 10, 100 or 1000 kernels?

Scalability Issues

Some examples:

- Increasing number of spaces per kernel:
  - 10 spaces on one kernel!
  - 100 spaces on one kernel?
- Increasing number of kernels with one space (assuming retrieval by URL):
  - 10 kernels each with one space!
  - 100 kernels each with one space?
- But, ...
  - request to multiple kernels
  - request to shared spaces

We therefore argue that proof of scalability by simulations might not be enough, nor really feasible, as there are ***too many parameters*** influencing the results!

Scalability Analysis

- Tool for design time analysis of desires and requirements with respect to scalability
- Need for an ‚offline' evaluation methodology
  - Determine scalability bottlenecks
  - Find alternative, still satisfiable and more scalable realizations
- We want to define the methodology to deliver such design time evaluations

Scalability Factors

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Two Dimensions

- There are two dimensions to a middleware that influence its scalability
  - The exposed functionality - the service delivered to the clients - *the functional properties.*
  - The internal behavior of the system that is not obvious or visible to clients at interaction time - *the non-functional properties (NFP).*

Functionals (1/3)

- Publishing information
  - out(Triple t, URL space): void
  - out(Set<Triple> t, URL space, Time lease): void

  - *Atomically writes a single triple into the space.*
  - *The operation makes no guarantee if and when the triple will be available in the space (unordered semantics).*
  - *The client is immediately free to perform further activities.*
  - *The client has to provide a resolvable URL which identifies a space.*

According Triple Space API, 5.11.2007

Functionals (2/3)

- Retrieving information
  - rd(Template t, URL space, Time timeout): Set<Triple> s
  - rd(Template t, Time timeout): Set<Triple> s

  - *Returns one match of the given template.*
  - *The match may be a set of triples*
  - *The operation makes no guarantee as to when the match would be returned to the client.*
  - *A timeout is provided to give a temporal bound for returning a match. If no match has been found by the timeout period, an empty set is returned. This does not make any statement regarding the existence of a match in the space.*
  - *No timeout can be specified by providing a null value.*

According Triple Space API, 5.11.2007

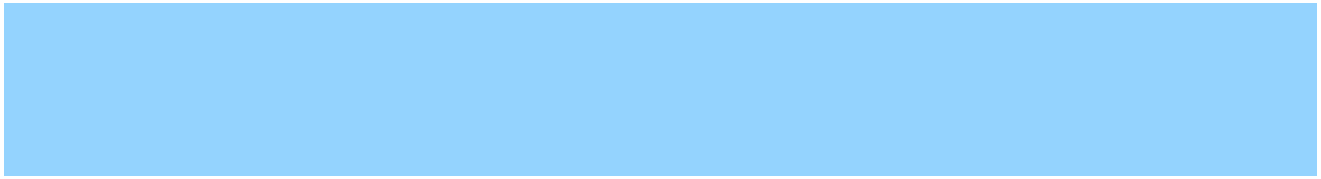
Functionals (3/3)

- *Query complexity*
  - Ranging from triple patterns <*:tripcom ?p ?o*> to arbitrarily complex queries.
  - Query resolution (reasoning).
- *Explicit vs. inferred data*
  - Publication at data level – no reasoning, multiple copies.
  - Retrieval at knowledge level – inference, materialization, only „one“ copy.
    - Local reasoning vs. distributed reasoning.
- *Transactions*
  - E.g. when publishing sets of triples within an atomic operation.

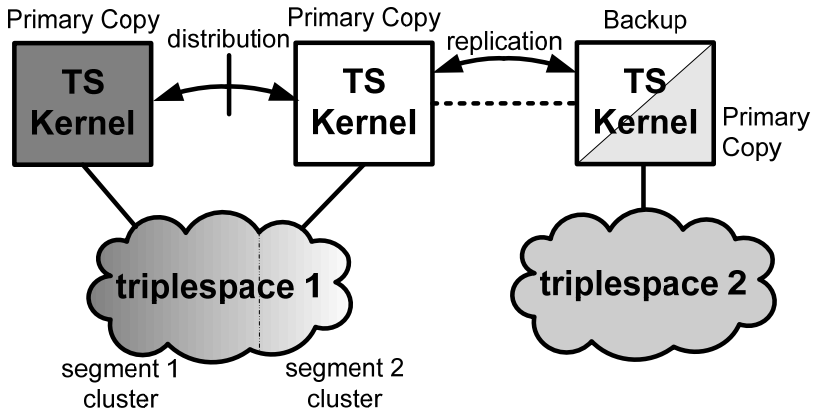
Non-Functionals

TS related
(dependability)

data/query
related



Technical Means for NFP



- *Redundancy*
  - duplication of functionality (n-out-of-m, n < m).
- *Recovery*
  - Re-installation of previous system state.
- *Load balancing*
  - decentralization of processes
    - by *replicating* data.
    - by *distributing* data (partitioning, clustering).
- *Synchronization*
  - eager, buffered, lazy...

NFP and their Realization (1/3)

- *Fault-Tolerance*
  - Redundancy: prevention, 1-out-of-2
  - Recovery
- *Availability*
  - Load balancing: 1-out-of-N
- *Reliability*
  - Redundancy: prevention, 2-out-of-3
- *Completeness*
  - No distribution of data

NFP and their Realization (2/3)

- *Consistency*
  - No replication: no system-caused inconsistency
  - Synchronization
- *Correctness*
  - No false-positives, a query engine issue, completeness
- *Durability*
  - Recovery: persistency is given by storage
- *Latency*
  - Load balancing

NFP and their Realization (3/3)

- Scalability
  - The trade-offs between *non-functional properties* and between *functionals* and *non-functionals* need to be analyzed in order to achieve a feasible level of scalability.
  - An appropriate configuration for the desired behavioral and structural realization and the corresponding scalability level has to be selected.
  - The configuration delivers a (limited) means to determine the expected degree of fulfillment for each of the properties.

Scalability Trade-Offs

Completeness ←→ Availability

Load balancing by distribution

Consistency ←→ Availability

Load balancing by replication

Consistency ←→ Fault Tolerance

Replication could be hidden

Reliability ←→ Response Time

Completeness ←→ Response Time

Consistency ←→ Response Time

Durability ←→ Response Time

Non-local writing results in latency

Scalability Rule of Thumb

- Depending on the desired functionality and non-functionality, the space middleware has different possibilities to provide a scalable infrastructure.

The richer functionality the middleware provides, the less can be guaranteed about the non-functional properties and scalability.

Scalability Configurations

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Configurations

- Descriptions of the functional and non-functional
  - desires
  - requirements and
  - importance of each property

- A configuration must not describe a scalable realization
- Configurations deliver a means to analyse and evaluate (at design time) a desired implementation
- Existing configurations serve as guidance to the development of feasible solutions;
- i.e. configurations are written and applied by the developers and owners of spaces.

Configurations

- Relevant non-functional properties
  - (Service/TS) Availability
  - Reliability
  - Completeness
  - ~~Correctness~~
  - Consistency
  - ~~Durability~~
  - Latency
  - ~~Scalability~~

Not tradable properties in TripCom:
- correctness of query engine
- durability of storage
- scalability of TripCom

  - Security (orthogonal), Safety (kernel), fault tolerance (out of scope)

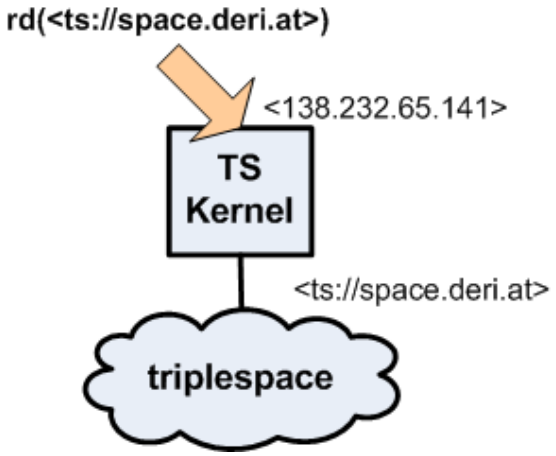
Configurations: The dimensions

- Availability (Load Balancing)
  - Distribution
  - Replication
- Reliability (Redundancy: replication)
- Completeness
- Consistency
- Latency

- Coordination primitives
- Template matching / query complexitiy
  - Triple patterns
  - Complex RDF queries
- Transactionality
- Inferrence

Scalability Levels (1/3)

- Simplest (and most scalable) approach
  - The target space is indicated by a resolvable URL
  - Distribution is client-driven
  - Discovery by use of a DNS-like procedure
  - Ensures at least local scalability



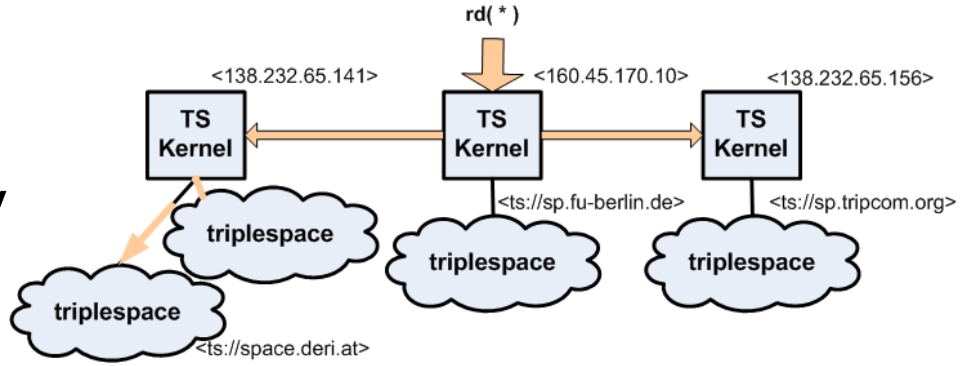
Scalability Levels (2/3)

- Most complex approach – likely not scalable
  - Access to spaces without indication of a URL
  - (Knowledge-driven) retrieval on the entire Semantic Web
  - Query forwarding, distributed discovery of relevant spaces
  - Distributed reasoning to integrate distributed information sources/spaces or large scale (local) reasoning after transfer of triples

Scalability Levels (3/3)

- Loosening classical IR guarantees is of benefit to achieve scalability
  - Access to space(s) without indication of a URL
  - Best effort retrieval – no completeness
  - No guarantees about consistency
  - Rather data than knowledge-driven

- Performance
  - Search scope
  - Discovery strategy



Scalability Levels++

- Further issues
  - Publication of sets of triples as atomic operation
    - **Issues with multiread/multiout**
  - Transactionality
    - Local transactions: data is visible to other hosts after commit
    - Tansactions in case of distributed writting, i.e. publication at remote hosts
    - Locking a space is unfeasible for distributed, decentralized settings

Evaluation Methology

- This is ongoing work!

- Some directions that we currently investigate:
  - Use the configurations (obviously)
  - Determine the required properties and the importance of the various factors

  - Potential techniques currently investigated:
    - Multi-Attribute Decision Analysis
      - e.g. Analytic Hierarchy Process (AHP)
    - Multi-Attribute Utility Functions
    - Sequential Decision Problems

Conclusions

- Scalability Deliverable
  - Due to January 31, 2008
  - Many open PMs to deliver!
- Scalability in TripCom
  - data access time (latency)
  - frequency and parallelism
  - number of spaces, number of kernels, number of users
  - number of internal messages
- Scalabiltiy in TripCom more complex than in traditional structured P2P overlays (DHT) (alternative realizations)
  - Functional and non-funcational aspects
  - Trade-Offs
- Scalability Configurations
  - Descriptions of realizations with respect to the scalability factors
  - Applied for the design time evaluation and analysis

Thank you!