The Smart-M3 Semantic Information Broker (SIB) Plug-in Extension: Implementation and Evaluation Experiences

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Agenda

- ***Smart Environment***: a call for interoperability
- ***SOFIA project*** and ***Smart M3*** architecture
  - pros: interoperability at information layer
  - cons: hard to extend with new core features
- Plug-in Interface
  - dynamically extend Smart M3
- Profiling service
  - performance indicators based on Plug-in and regular KPs

Smart Environment & Information Interoperability

- From Personal/Ubiquitous Computing to ***Smart Spaces***

- Smart Environment paradigm: “anywhere, anytime, anything”
  - ***cooperation and data sharing*** to enhance ***information availability*** and enable new services and features
  - need to overcome ***standardization issues*** related to the physical world

SOFIA project: Motivations and Principles

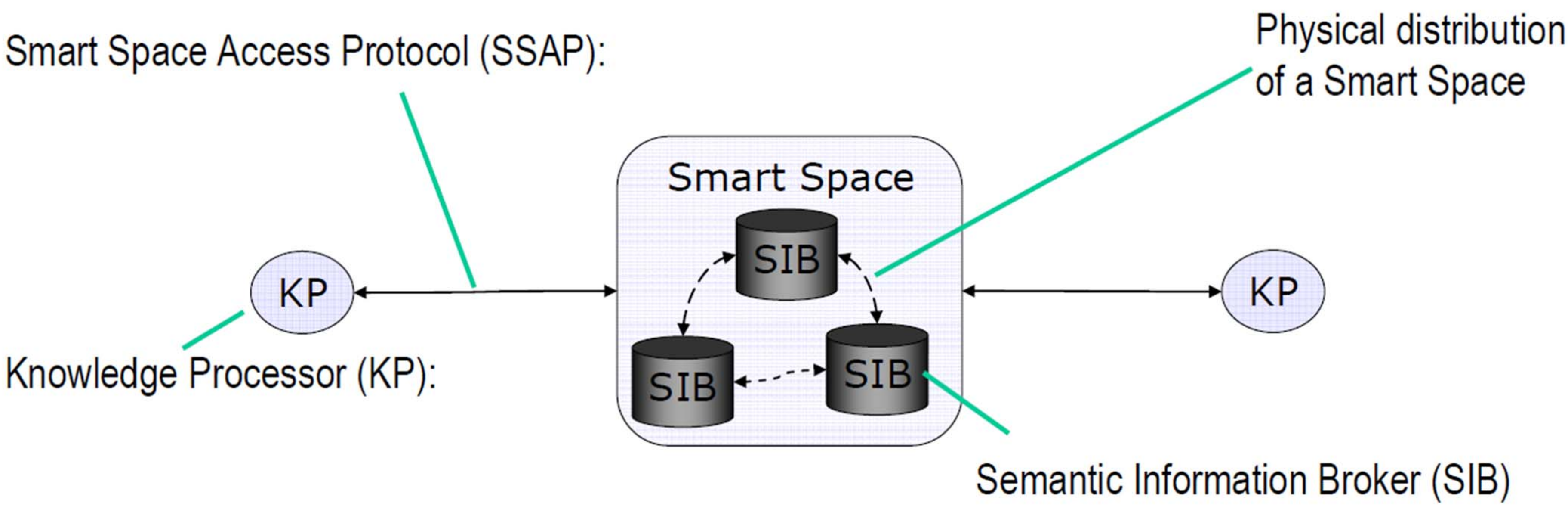
- ***SOFIA***: Smart Objects For Intelligent Applications
  - http://www.sofia-project.eu/
- ***Mission***: InterOperability Platform (IOP) to overcome standardization issues
  - ***information interoperability***
  - ***cooperation between*** application and ***smart services***
- IOP enables a ***seamless access to the distributed content*** from heterogeneous devices, ranging from smartphone to desktops

Smart M3: IOP Nokia Implementation

- ***Smart M3: Multi-vendor, Multi-device, Multi-domain***
  - Linux-based reference implementation developed by Nokia
- Communication based on ***blackboard approach***: entities do not know each other
- ***Smart M3 IOP: interoperability based on semantic consensus, but in a localized manner***
  - no globally accepted semantic or ontology
  - devices share and access information based on **locally agreed** semantics
- Smart M3 does not depend on the underlying communication

Smart M3 Architecture

- ***Smart Space***: scope of interesting information
- ***Semantic Information Broker*** (SIB): maintains shared data stored as RDF triples
- ***Knowledge Processors*** (KPs): external entities interacting each other by publishing/reading data to/from the SIB
- ***Smart Space Access Protocol*** (SSAP): lightweight communication protocol with simple and efficient operations, e.g., join, leave, insert, remove, update, query, subscribe, unsubscribe



Smart M3: Pros

- Information published through shared Semantic Information Brokers (SIBs): ***decoupled interaction***
- Information based on ***common ontology*** models and common data formats (RDF)

- ***Smart-M3 is device, domain, and vendor independent***: maximum flexibility, simple availability
  - ***user***: freedom of choice (multi-vendor)
  - ***device manufacturer***: seamless operations with every devices (multi-device)
  - ***application developer and service company***: focus on consumer interests gaining competitive edge (multi-domain)

Smart M3: Cons

- Smart M3 is still growing and under development
  - http://sourceforge.net/projects/smart-m3/
- Ongoing work
  - access control and ***security management*** (SSAP secure implementation)
  - service discovery and ***composition***
- Open issues
  - SIB distribution protocol to create a ***distributed shared repository***
  - ***context-awareness*** support: sustaining scalability and efficient management of available resources/services
  - ***features statically defined*** at compile-time

Enhancing M3 Flexibility

- Need to clearly separate aspects related to application logic from general purpose features
  - full interoperability and maximum re-usability
  - ***only KPs can offer services***, always using SSAP
  - ***SIB features are defined at compile-time***, no dynamic addition is possible at run-time
- Goal: supporting the ***dynamic addition of management core features***
  - depending on the context and the capability of the hosting node
  - different scope and operating layer compared to KP
  - possible useful features: node characterization, information management, garbage collecting
- Joint contribution by University of Bologna and Nokia

Plug-in Interface Solution to Dynamically Add Features

- General purpose API to ***dynamically register and execute third-party services (plug-ins)*** to provide additional features
  - exclusive and privileged access to stored data
  - no communication overhead: directly interact with the RDF datastore

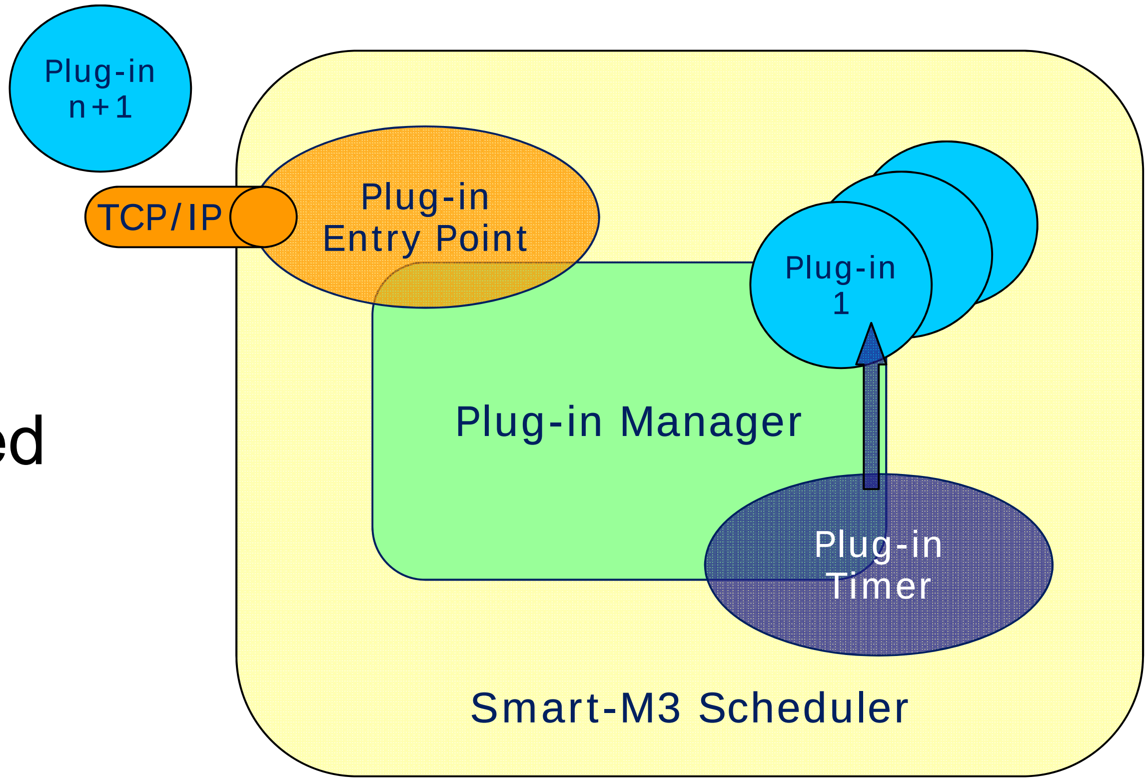
- Services and extensions developed according to a well-defined programming discipline in compliance with a ***standard template***
  - ***evaluateState***: checking executing conditions
  - ***run***: starting plug-in execution
  - ***stop***: ending plug-in execution, depending on execution time and/or scheduling needs

Plug-in Implementation Details

- Dynamic architecture: plug-ins implemented through ***dynamic linked library*** (Shared Objects)
  - a .so can be dynamically loaded/unloaded and linked ***at SIB execution time***
  - ***additional features separated from SIB executable***, reducing its size and used disk space
  - ***SIB customization***: provide additional features/plug-ins only when required
- ***Efficient check of plug-in template compliance*** through proper functions provided by the OS

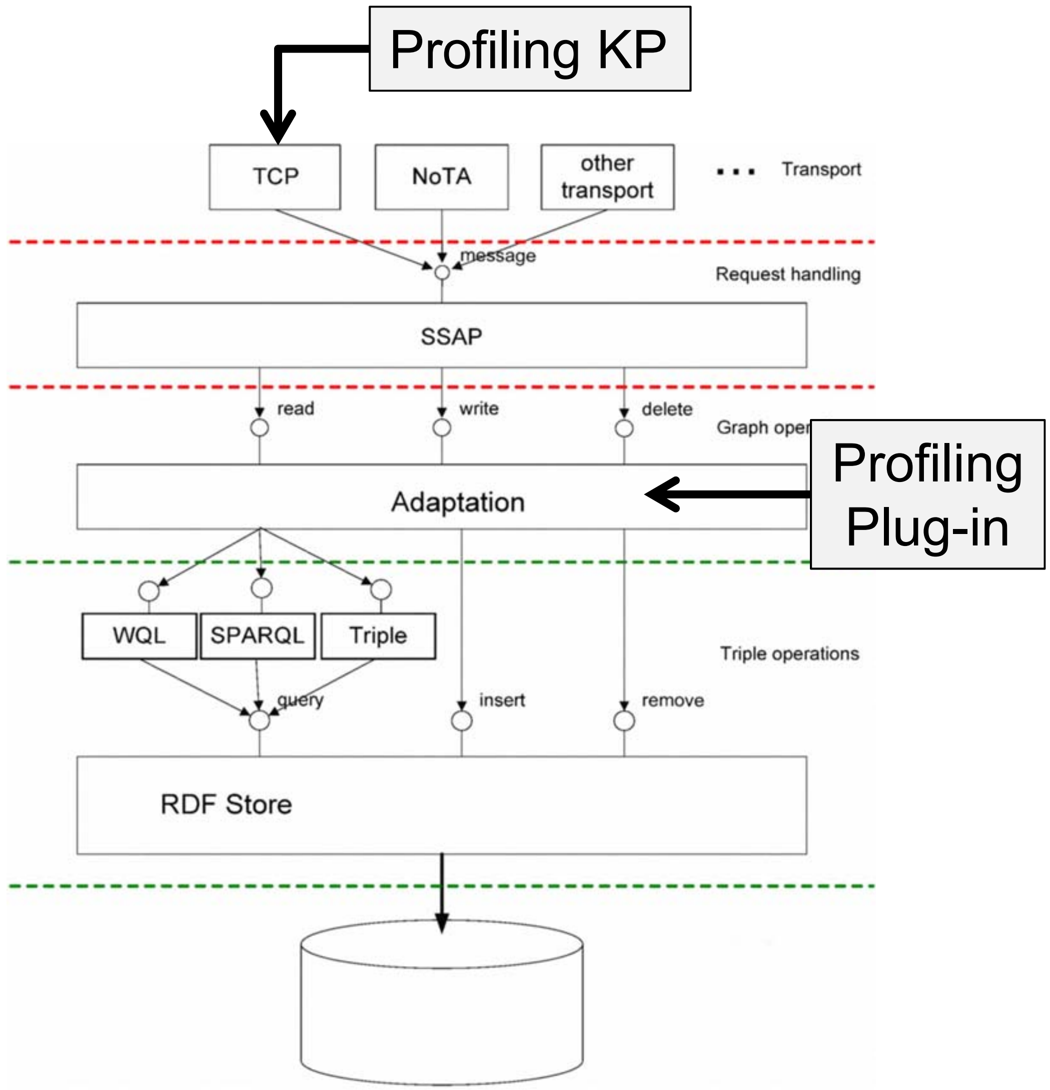
Plug-in Interface: Components and Behavior

- Plug-in Entry Point
  - un/register plug-in extensions
  - check template compliance
- Plug-in Manager
  - periodically activates registered extensions
- Plug-in Timer
  - fairness enforcement in terms of plug-in execution time



SIB Profiling: Relevance and Advantages

- Profiling service
  - dynamically evaluate ***SIB performance***
  - useful to compare SIBs
- ***Two alternative approaches*** to gather performance
  - Profiling KP
    - based on a regular KP
    - SSAP-based access to RDF store in competition with other KPs
  - Profiling Pug-in
    - implemented as a plug-in
    - direct and exclusive access to the RDF store



KP and Plug-in Solutions Comparison

- ***Profiling Plug-in***: best possible performance without any interference, such as traffic overhead or concurrent KPs
  - ***ideal upper bound*** KPs are not able to exceed
- ***Profiling KP***: performance affected by SSAP overhead and current load
  - achieved value ***closer to what is actually possible*** for a regular KP

- ***Complementary solutions***: comparison of performance achieved by Profiling Plug-in and KP to ***estimate current load on the SIB***

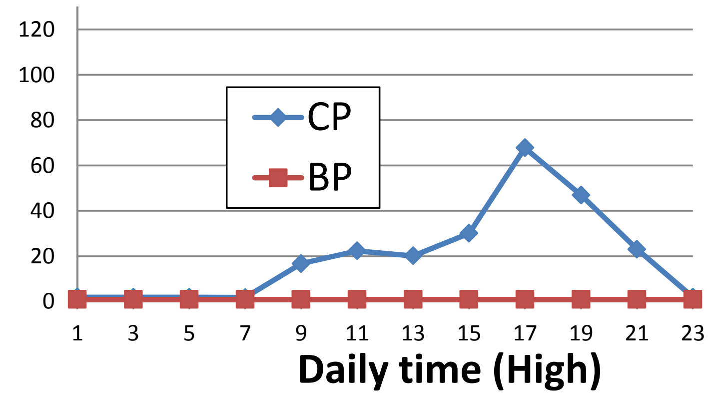
Performance Indicators

- Different parameters to ***quantitatively evaluate SIB performance***
  - complementary performance indicators useful in relation to KP objective
  - periodically computed and locally stored as RDF triples
- Current Perf.: CP = (KP insert + 10 * KP query + KP delete / 10) / 3
  - ***currently available*** performance on SIB
  - useful for KPs interested in ***quickly retrieving data***
  - computed every two hours, to monitor the daily workload
- Best Perf.: BP = (plug-in ins. + 10 * plug-in q. + plug-in del. / 10) / 3
  - best performance achievable ***in ideal conditions***, i.e., no concurrent KPs, no communication overhead
  - useful for ***long lasting KPs***
  - computed once a day (unlikely to vary)
- Relative Performance: RP = CP / BP
  - RP = 1 → current performance equal to best performance
  - useful to ***balance workload*** on available SIBs

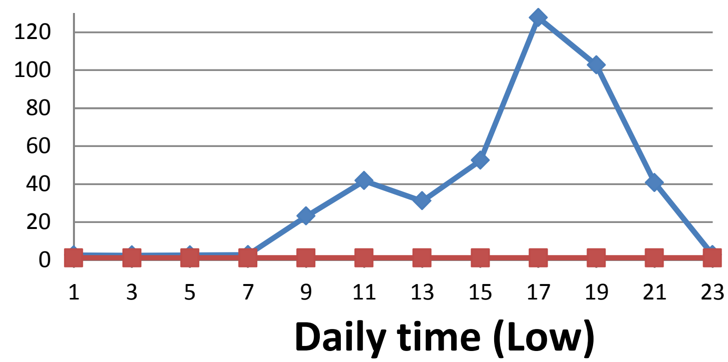
Testbed Details

- ***Two SIBs with different capabilities***: Linux + ad-hoc IEEE 802.11g link
  - High: Intel Core2 Duo P8400 2.26GHz, 3GB RAM
  - Low: Intel Pentium M processor 1,10GHz, 500MB RAM
- ***Workload emulation***
  - 8/2/1 inserts/deletes/query for each cycle, RDF triples queried at the end
  - performance indicators vary in relation to ***node capabilities*** and ***workload***

Daily time	Workload Conditions
1:00, 3:00. 5:00, 7:00, 23:00	No workload KPs
9:00	1 workload KP, 18 cycles
11:00, 13:00	1 workload KP, 100 cycles
15:00	2 workload KPs from different nodes, 20 cycles
17:00	2 workload KPs, from different nodes, 40 cycles
19:00	2 workload KPs, from different nodes, 20 and 40 cycles
21:00	1 workload KP, 40 cycle



BP = 0.86s



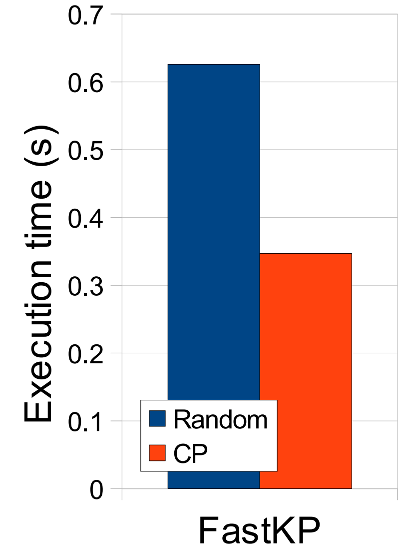
BP = 1.24s

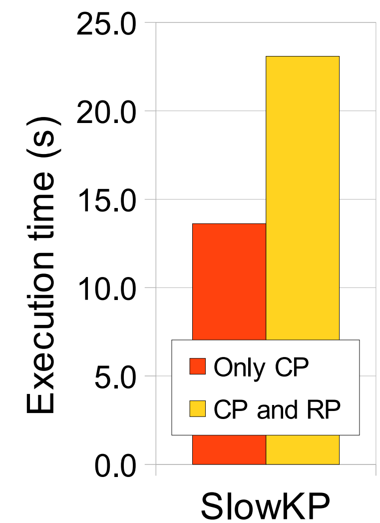
Performance Analysis

- ***Two KPs with differentiated requirements***
  - FastKP: few operations with strict delay requirements
  - SlowKP: several operations, without strict delay requirements

- ***SIB selection based on CP/BP/RP***
  - FastKP: random vs. lowest CP
    - only FastKP executes
    - ***execution time lowers*** from 0.63s to 0.35s
  - SlowKP: lowest CP vs. best RP
    - FastKP already executing on SIB with best CP
    - execution time increases (not an issue), but ***workload fairly distributed*** among SIBs

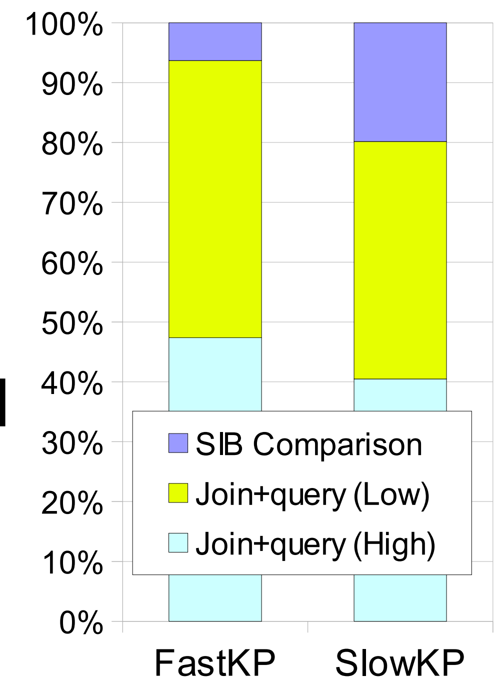
Node	High	Low
Both Fast/ SlowKP use CP	4.64%	0.00%
FastKP uses CP, SlowRP uses RP	1.01%	3.12%





Overhead for Gathering Performance Indicators

- ***Overhead due to performance indicators***
  - join available SIBs
  - query CP/BP/RP
  - evaluate SIB



- Joining, gathering, and comparing overhead ***largely lower than execution time***
  - suitable even for FastKP with strict delay requirements
  - SIB joining has the greatest impact

	FastKP		SlowKP	
	Execution (s)	**Comparison (s)**	**Execution (s)**	**Comparison (s)**
Both FastKP and SlowKP use CP	0.35	0.02	13.62	0.04
FastKP uses CP, SlowRP uses RP	0.35	0.02	23.08	0.03

Conclusions

- SOFIA project and Smart M3 IOP support interoperability of heterogeneous devices
- Proposed Plug-in API allows ***SIB dynamic customization***
  - keeping SIB architecture ***very lightweight***
  - supporting domain- and deployment-specific ***additional features***
- Profiling service: performance indicator ***coupling plug-in and KP approaches***
  - KPs can dynamically select the SIB best fitting their requirements

- Ongoing work
  - proper and well-defined ontology for SIB profiling
  - dynamic federation of distributed SIBs

Any Questions?

Thanks for your attention ☺

Questions time…

Prototype code: http://sourceforge.net/projects**/smart-m3**/

Additional information: http://www.**sofia-project**.eu/