Dynamic Adaptive Middleware Services For Service Selection In Mobile Ad-Hoc Networks

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About the authors

- The University of Sao Paulo is the largest higher education and research institution in Brazil. It has outstanding projection around the world, especially in Latin America, and develops a large number of Brazilian masters and doctors who work in higher education and research institutes.

- Rogério Dutra is a PhD student at Politechnique School of USP, with a master degree in datamining techniques. Currently, working for SAP as Principal Consultant in BI and CRM analitics.

- Dr. Moacyr Martucci Jr. in full professor at Politechnique School of USP, with more than 100 publications in the field of open distributed systems and management information systems.

AGENDA

1. Problem statement and proposed solution
2. Architecture and Selection Process
3. Implementation and Results
4. Conclusion and Future Work
5. Main References

Problem Statement

How to enhance service selection in Mobile Ad-Hoc Networks (MANETs)

- In MANETs environment, service discovery would enable devices and services to properly discover, configure, and communicate with each other.

- Discovery comprises search and selection. These two mechanisms can be independent or integrated.
- Although service selection is a basic feature for service discovery approaches, it has been underestimated or simply ignored in most of discovery solutions found in literature.
- Usually, a consumer issues a query to search services based on functional properties, advertised by service providers or intermediate nodes in the network, resulting in a set of similar services.
- To complete the discovery process, a selection based on additional service non functional properties is necessary.

- If the service selection is **not performed properly**, the search will generate non optimized results, causing an **unnecessary overhead** in MANETs environment or **low** Quality of Service (QoS) **perception** from the consumer point of view.

Proposed Solution

Dynamic Adaptive Middleware Services for Service Selection in MANETs

- To overcome the challenges of Service Selection in MANETs, this paper proposes a novel selection solution called Dynamic Adaptive Middleware Services for Service Selection (DAMS-SS) in MANETs, to satisfy the following requirements:
- Cluster search results, based on unsupervised learning of Self-Organizing Map algorithm, without consumer interaction or hard-coded assumptions;
- Define hierarchical cluster relationships, using adaptive and incremental supervised learning of an Adaptive Decision Tree algorithm;
- Adapt consumer service request, managing uncertainty in QoS attributes definitions from the consumer perspective, using a Fuzzy Inference algorithm.

- The expected benefits of DAMS-SS proposed solution are:
- Enhance service selection capabilities of existing functional middleware solutions, encapsulating datamining algorithms as middleware services based on a service architecture;
- Transform data gathered from MANETS into comprehensible information to support consumer decision on best service choice selection;
- Propose a structured process for service search refinement combined with a reactive and proactive selection method.

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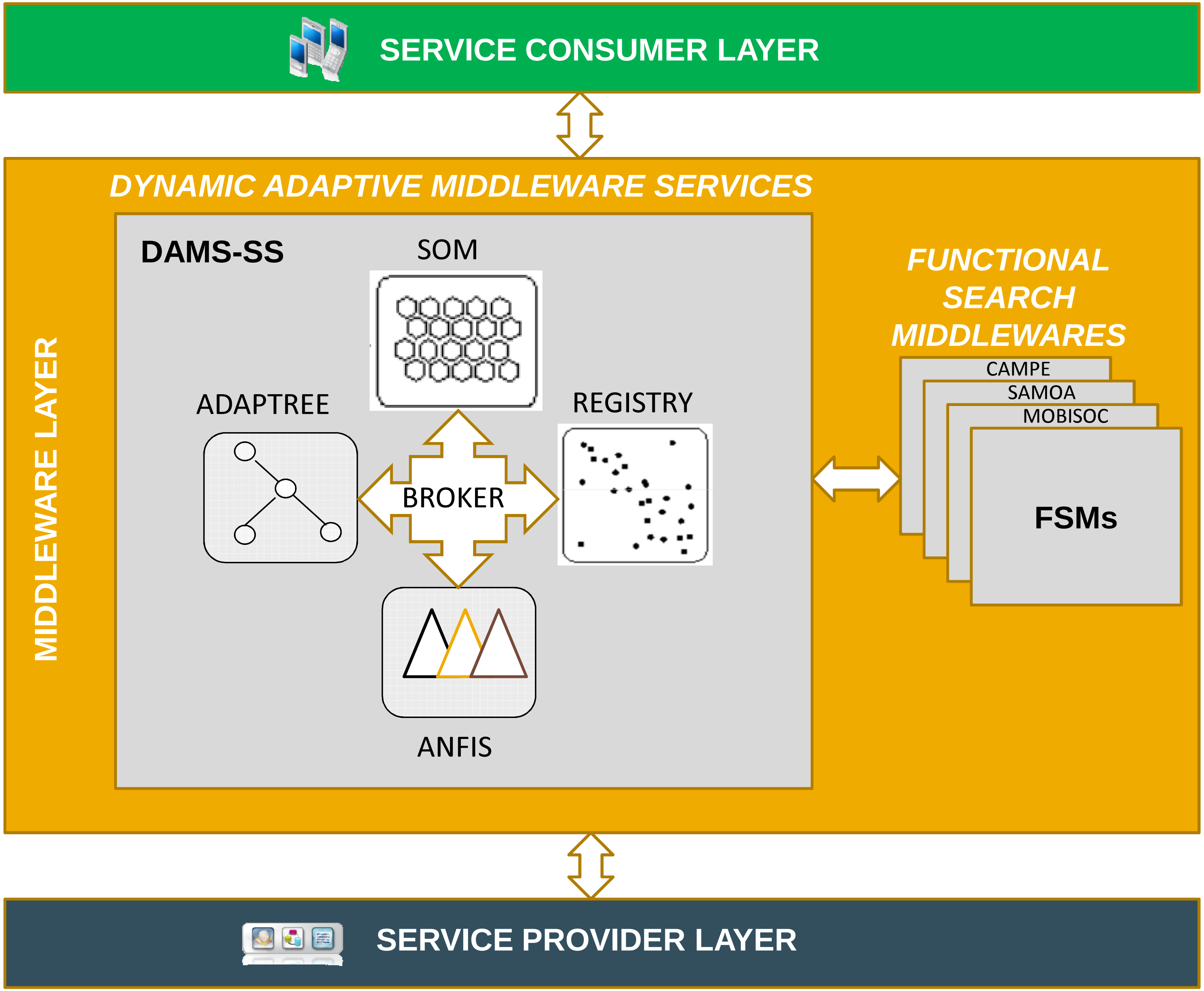
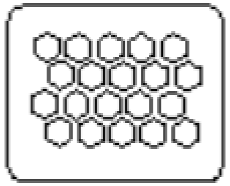

SERVICE CONSUMER LAYER
DYNAMIC ADAPTIVE MIDDLEWARE SERVICES
MIDDLEWARE LAYER
DAMS-SS
SOM
ADAPTREE
REGISTRY
BROKER
ANFIS
FUNCTIONAL SEARCH MIDDLEWARES
CAMPE
SAMOA
MOBISOC
FSMs
SERVICE PROVIDER LAYER

Service Oriented Architecture (SOA)

Core components for Dynamic and Adaptive Service Selection in MANETs



SOM

Self-**O**rganizing **M**ap

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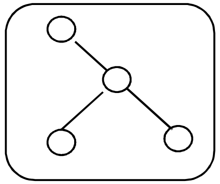

ADAPTREE

Adaptive Decision **Tree**

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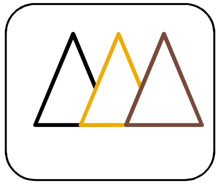


ANFIS

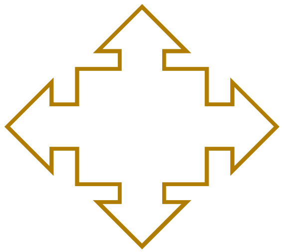
Adaptive **N**etwork-based **F**uzzy **I**nference **S**ystem

=

DAMS

Dynamic **A**daptive **M**iddleware **S**ervices

SOA components for Service Interoperability implemented by REDS

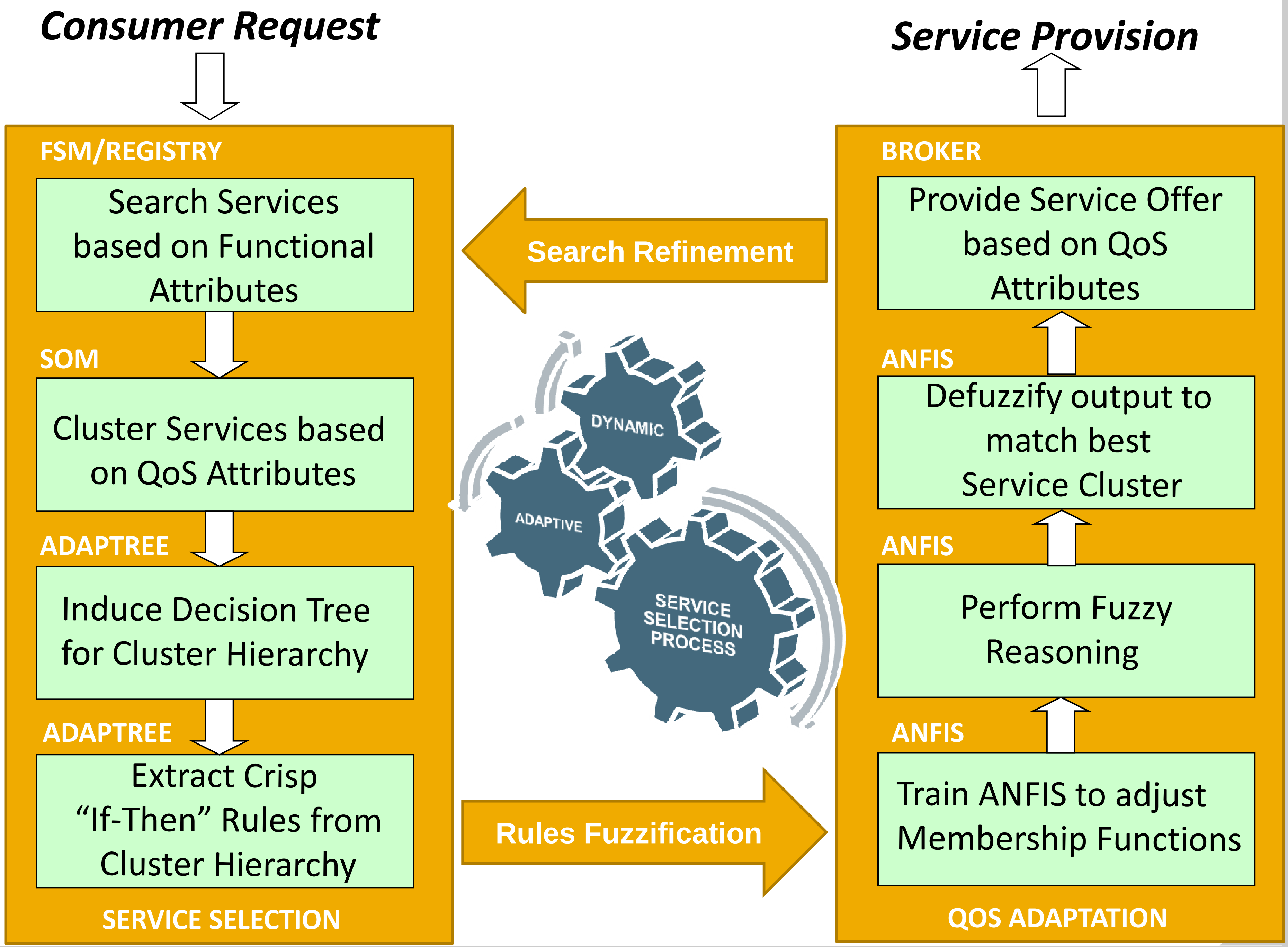


BROKER

+

REGISTRY

REconfigurable **D**ispatching **S**ystem


Consumer Request
Service Provision
FSM/REGISTRY
Search Services based on Functional Attributes
SOM
Cluster Services based on QoS Attributes
ADAPTREE
Induce Decision Tree for Cluster Hierarchy
ADAPTREE
Extract Crisp "If-Then" Rules from Cluster Hierarchy
SERVICE SELECTION
Search Refinement
DYNAMIC
ADAPTIVE
SERVICE SELECTION PROCESS
Rules Fuzzification
BROKER
Provide Service Offer based on QoS Attributes
ANFIS
Defuzzify output to match best Service Cluster
ANFIS
Perform Fuzzy Reasoning
ANFIS
Train ANFIS to adjust Membership Functions
QOS ADAPTATION

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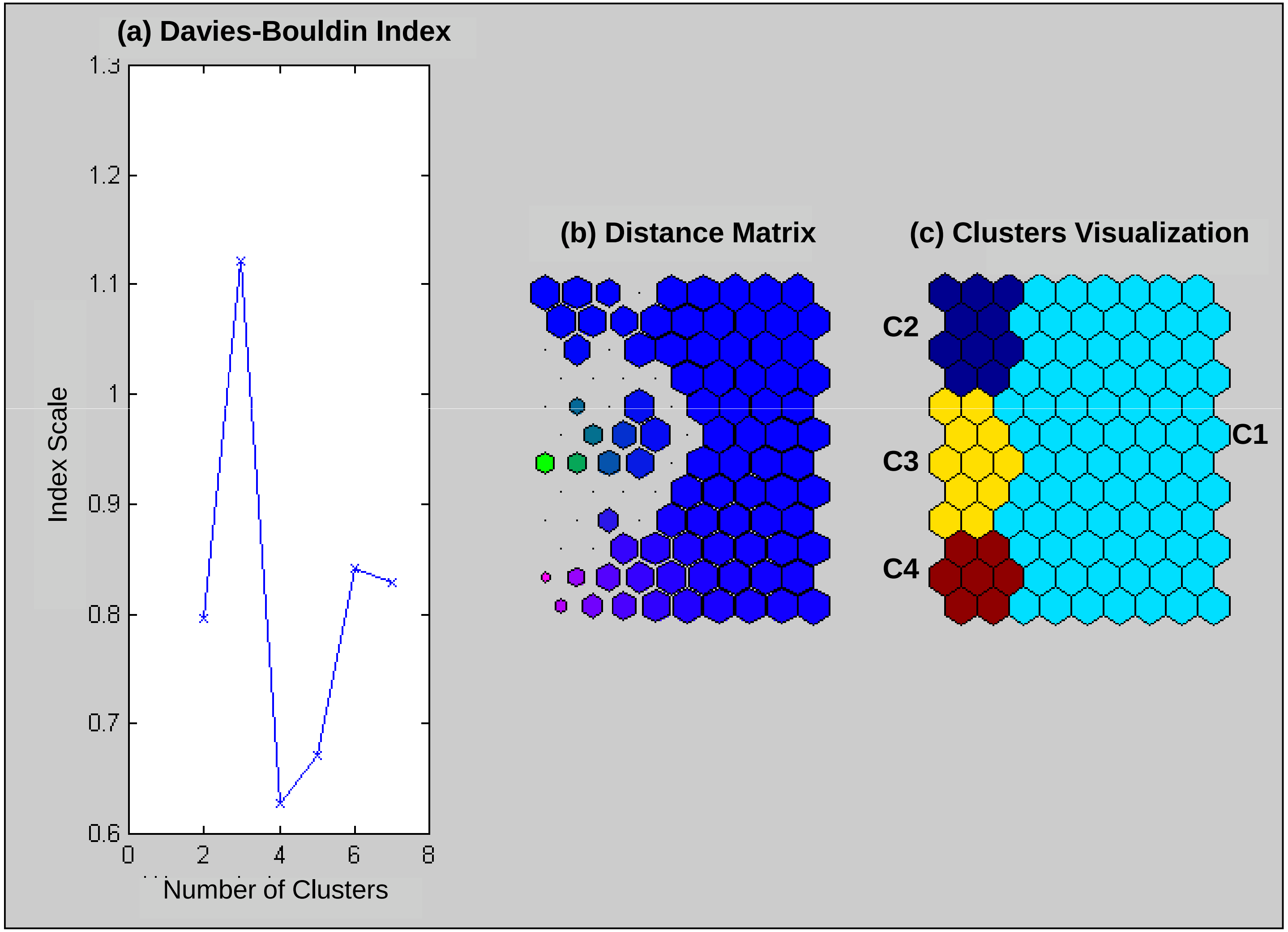
Self-Organizing Map (SOM)

Cluster Services based on QoS attributes



Service QoS Attributes

Service non functional attributes used for service clustering in SOM

- From the service consumer perspective, the following Service QoS attributes were considered for non terminal nodes in MANETs:

- **Availability** – The availability of a service is the probability that service is usable.

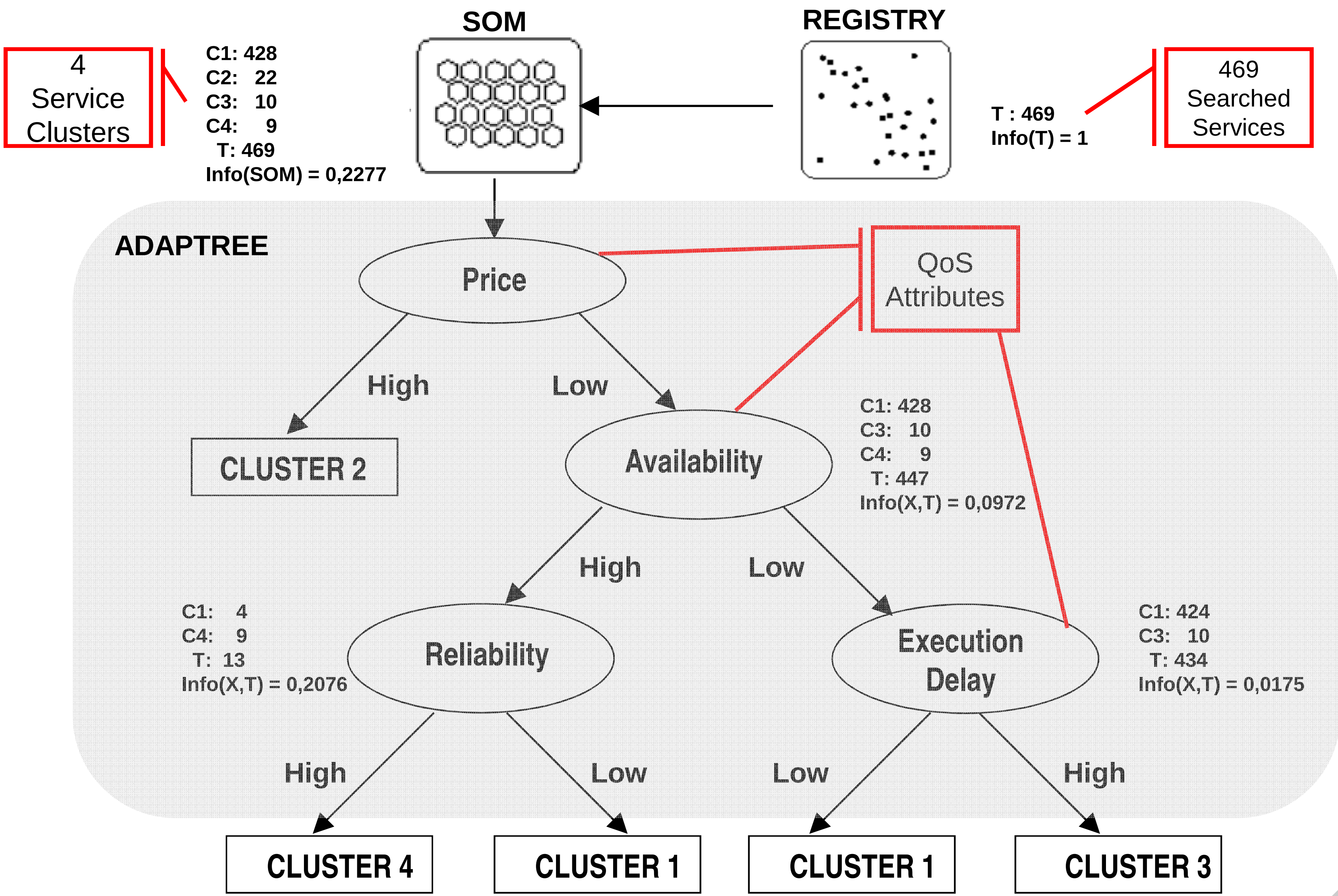
- **Price** – The price of a service is the fee that a service requester has to pay for using the service. The value of this QoS parameter is given by the service provider.

- **Reliability** - The reliability of a service is the probability that a service request is correctly responded, namely, the requester has received the expected results, within the maximum expected time frame indicated in the service description.

- **Execution Delay** - The delay of a service is a measure of duration between the time point when a service request is sent out and the time point when the results are received by the requester.

Adaptive Decision Tree (ADAPTREE)

Induce decision tree for service cluster hierarchy



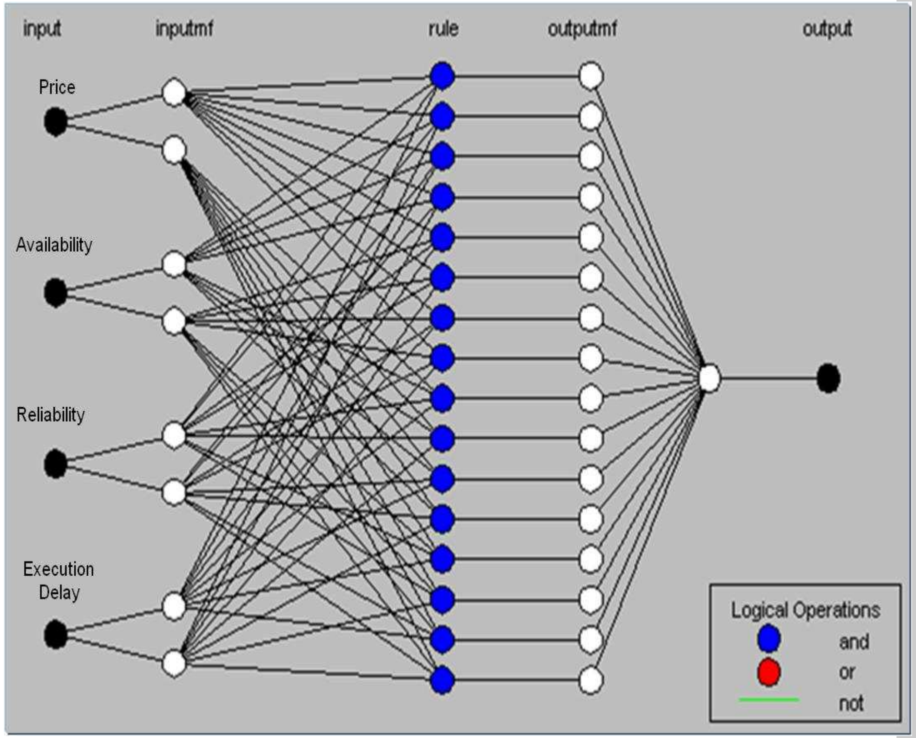
Adaptive Network Fuzzy Inference System (ANFIS)

Extract crisp rule set from ADAPTREE and build ANFIS

(a)

Rule #1. IF Price := "High" THEN
Service BELONGS TO Cluster2
Rule #2. IF Price:= "Low" AND
Availability:= "Low" And
Execution Delay := "High" THEN
Service BELONGS TO Cluster3
Rule #3. IF Price:= "Low" AND
Availability:= "Low" And
Execution Delay := "Low" THEN
Service BELONGS TO Cluster1
Rule #4. IF Price:= "Low" AND
Availability:= "Low" AND
Reliability:= "Low" THEN
Rule #5. IF Price:= "Low" AND
Availability:= "High" AND
Reliability:= "High" THEN
Service BELONGS TO Cluster4

(b)

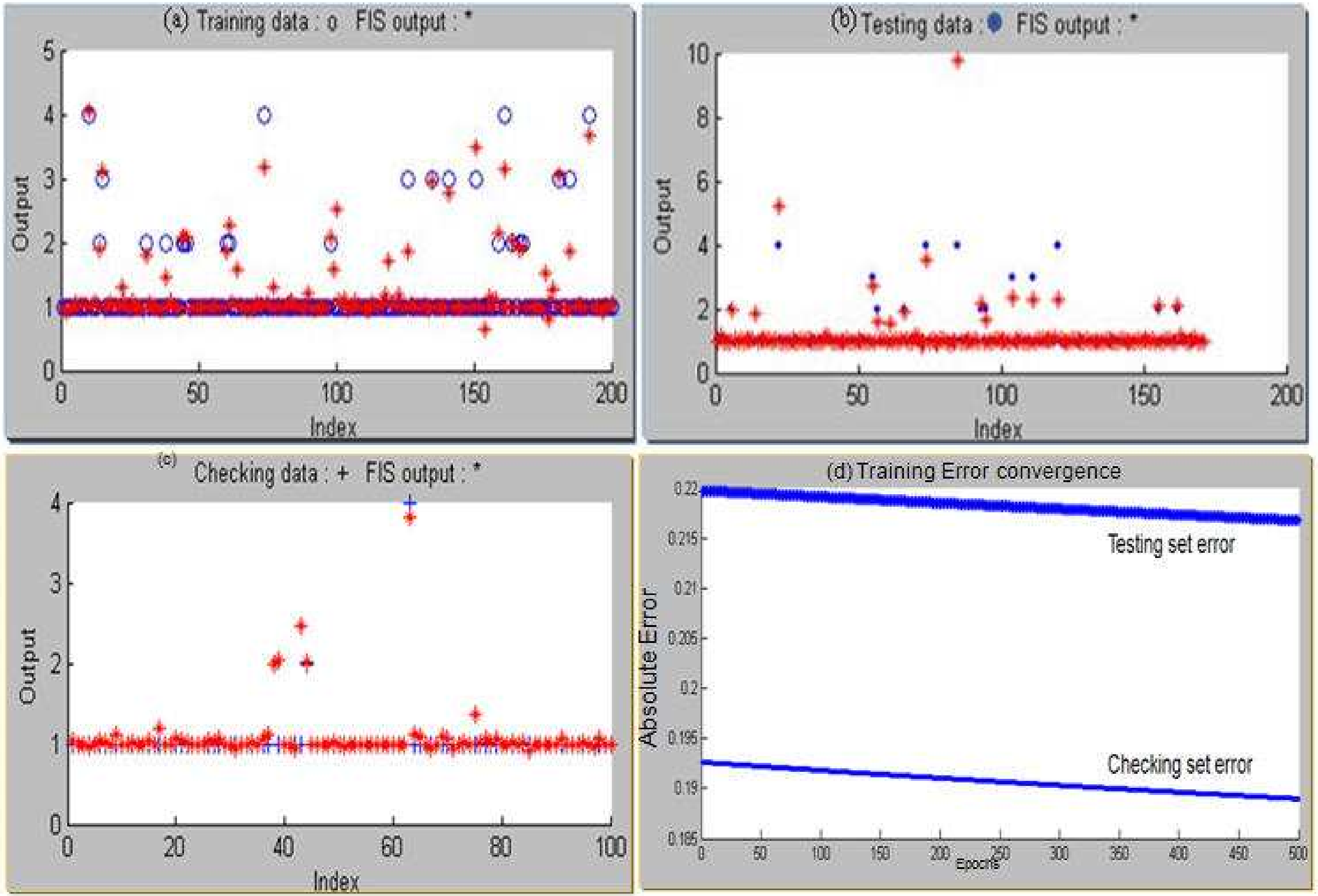


Adaptive Network Fuzzy Inference System (ANFIS)

Train ANFIS to adjust membership functions

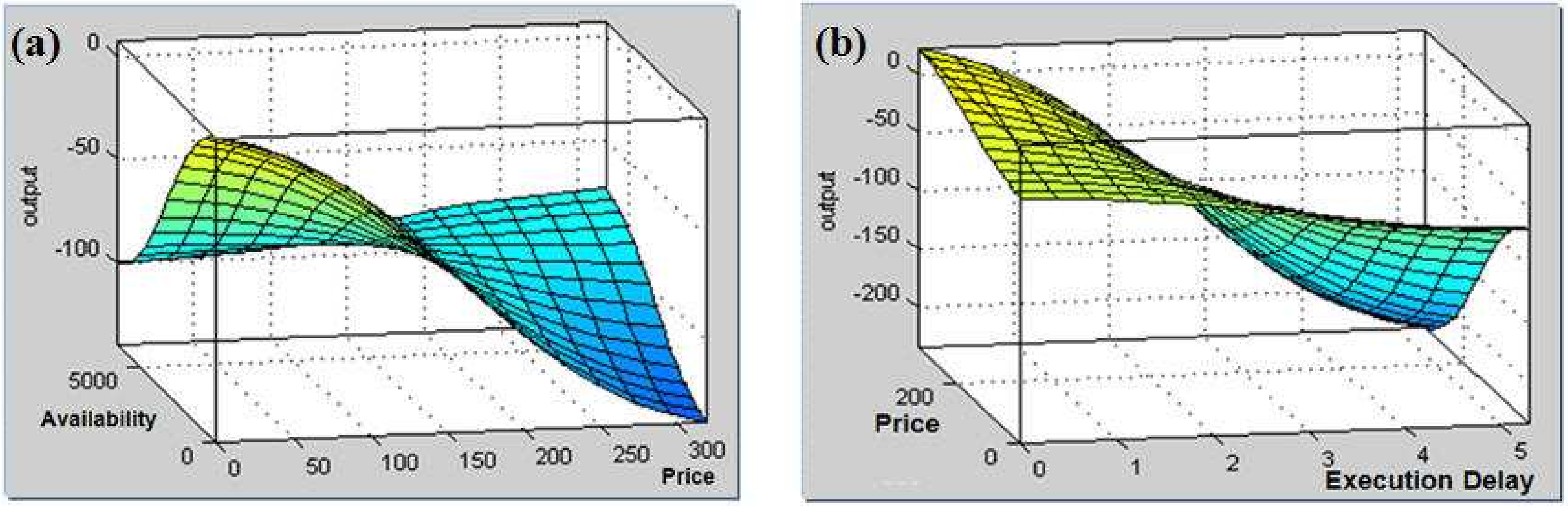
Adaptive Network Fuzzy Inference System (ANFIS)

ANFIS Inference results after fuzzy reasoning



Adaptive Network Fuzzy Inference System (ANFIS)

Defuzzify outputs to compare to non fuzzy QoS requirements



Examples of multi dimensional decision support surfaces

(a) Combining Availability with Price

(b) Combining Execution Delay with Price

- Matching Service Requests with Service Provisions, help service consumer to decide if current service provision match its fuzzy or not QoS requirements

Self-Organizing Map (SOM) Algorithm

Unsupervised Learning for Service Clustering

- Pros
  - Independence from a common service ontology to cluster services
  - Service clustering based on unrestricted number of service attributes
  - Iterative clustering “on the fly” ,capturing the last status of MANETs, in proactive or reactive modes
- Cons
  - Opaque algorithm, where cluster relationships cannot be gathered
  - Data uncertainty cannot be managed

Adaptive Decision Tree (ADAPTREE) Algorithm

Adaptive decision tree induction for service cluster relationships extraction

- **Pros**
  - Cluster relationships extracted in a IF-THEN rule set to train ANFIS, derived from decision tree.
  - Adaptive Finite State Automata to induce tree iteratively, avoiding all data consuptiom
  - Entropy gain measure to control decision tree induction, simplyfing rule descriptions.
- **Cons**
  - Supervised learning algorithm, requiring training
  - Data uncertainty cannot be managed

Adaptive Network Fuzzy Inference System (ANFIS)

Manage uncertainty in service clusters QoS definitions

- Pros
  - Combined fuzzy reasoning with Neural Nets supervised learning to adjust membership functions iteratively
  - Matching fuzzy QoS requirements to adapt service consumer requests to service provisioning
  - Matching crisp QoS requirements, defuzzing outputs to derived multi dimensional decision support surfaces.
- Cons
  - Supervised learning algorithm, requiring training
  - Large rule set combinations can affect fuzzy inference engine performance

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Conclusion and Future Work

- The combination of SOM, ADAPTREE and ANFIS transformed data, gathered from MANETs, into comprehensible information to support consumer decision on best service choice selection, while reducing the drawbacks of standalone service mining implementations.
- Our future work includes a implementation on real mobile devices to evaluate algorithms memory consumption and possible performance issues.
- To measure the trade-off between accuracy and usability, we intend to investigate and experiment with more QoS parameters, for example, networks parameters, evaluating the advantages and disavantages of proposed iterative selection process for MANETs environments.
- Although designed for MANETs, the proposed solution could also be used for service selection in distributed environments with fixed infra-structure networks, to support discovery in other service-oriented architectures, such as cloud computing, once the combination of mining algorithms could be encapsulated using any service language description.

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