A Coordination Protocol for Distributed Context Management Systems

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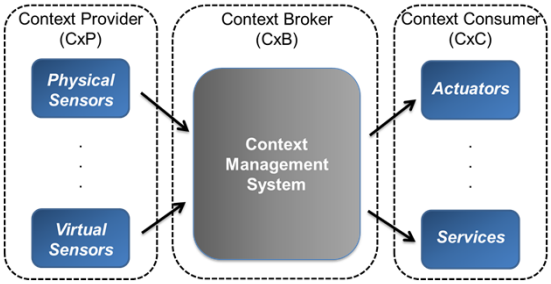
1. Motivation



- A Context Management System (CMS) offers the ability to:
  - reuse available resources (transport medium and context data)
  - manage context data from physical and virtual sources
  - allow support of niche applications

Motivation

- Key requirements for Context Management Systems (CMS) include:
  - Collecting data of any format
  - Enabling dynamic reconfiguration
  - Supporting real-time context data processing
  - Guaranteeing scalability and extendibility
- Examples for applications domains:
  - Transport and logistics
  - Personalized services
  - Smart grid
  - E-tourism
  - Agriculture and vehicular technology
  - Network services
- Reference implementations of context management middleware platforms are Gaia, PACE, Confab, and AURA CIS

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2. Context Management Systems

- Key requirements for context management systems (CMS):
  - Plug-and-Play: automatic discovery and configuration
  - Scalability: meaningful data distribution between nodes
  - Fault detection and recovery in case of node failure
  - Support for mobile subsystems
  - Efficient implementation, i.e. utilization of
    - Standardized data formats
    - Wide-spread transmission protocols
  - Additional requirements: data security, access control, …

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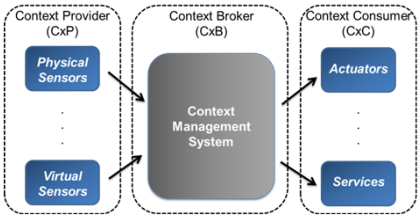
3. Centralized Context Management Systems



"Over-The-Top" implementation
REST-ful signaling

- Weakness of centralized system architecture:
  - Scalability problems
  - Limited support for mobile subsystems
- Solution:
  - Extension of the centralized context broker architecture to a distributed one
  - Introduction of Distributed Context Management Protocol (DCMP)

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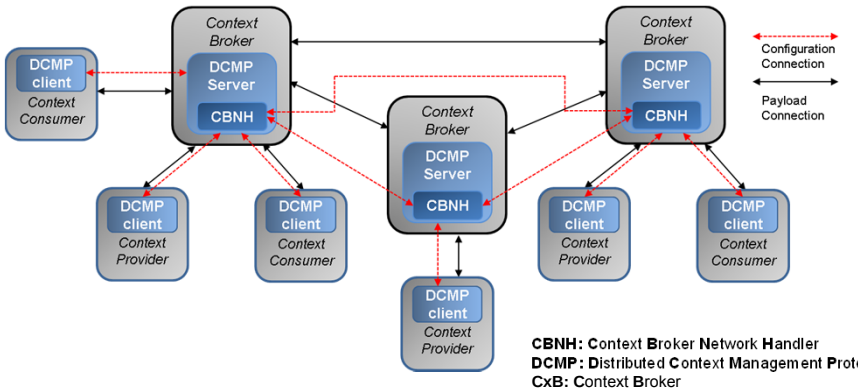
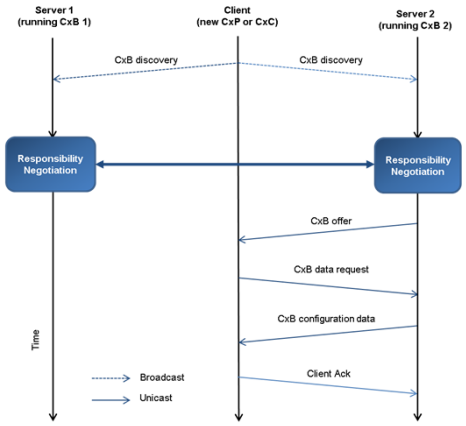
4. Distributed Context Management Architecture



Distributed Context Management Architecture

Auto discovery function of DCMP:

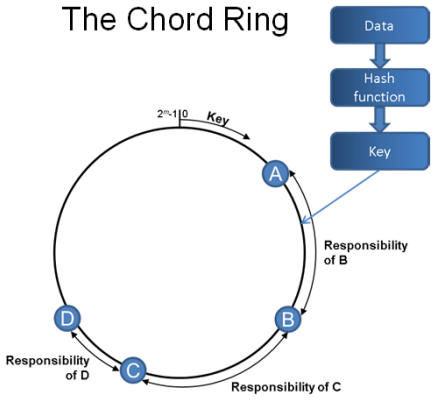


- Each client (CxC or CxP) sends a "***CxB discovery***" request
- Assignment to CxB is reconciled between CBNH entities (DHT based)
- Responsible CxB offers all necessary configuration data to the client
- CxP advertisement is similar to the centralized architecture

Distributed Context Management Architecture

Distributed Hash Tables (DHT)

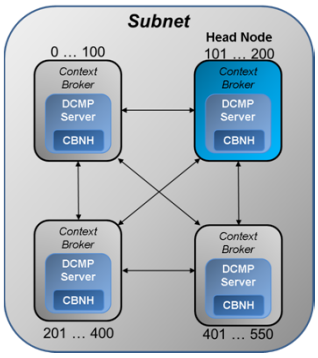
The Chord Ring



- Motivated by peer-to-peer systems and usually realized as "on the top" implementation
- Belongs to the class of decentralized distributed system that provides a lookup service
- Each node chooses a n-bit ID
- Each lookup key is also a n-bit ID
- Each node is responsible for storing keys "near" its ID
- Data keys are generated via hash functions

Distributed Context Management Architecture

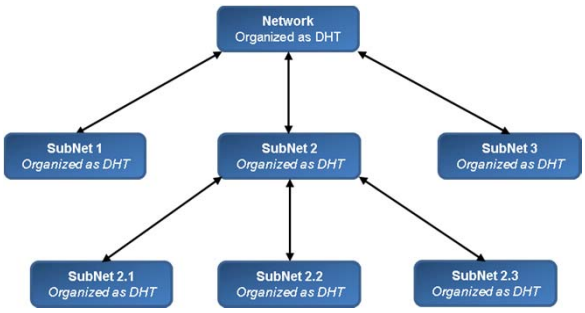
Reconcilement



- System consists of *m* CxBs
- Introduction of a CxB efficiency factor *α* (indicating CxB computing performance)
- Each CxB is responsible for a defined "range" of context data (keys)
- Distribution of clients between CxBs is organized with hash functions
- CBNH is responsible for key calculation

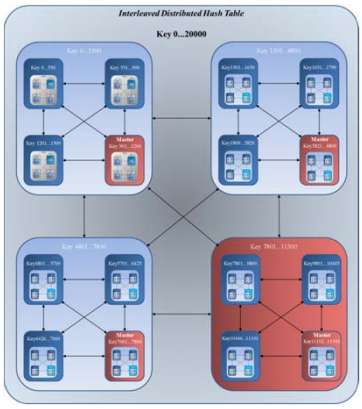
Distributed Context Management Architecture

Hierarchical Subnet Organization



- Each subnet is organized as a DHT
- One CxB in a subnet acts as "*Head Node*"
- Head Node is responsible for communication with upper network
- Key range of the Head Node in the upper network is equivalent to the key range of the whole subnet

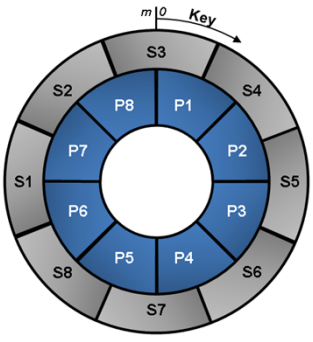
Nested Distributed Hash Table



- First CxB becomes Head Node and is responsible for communicating with nearby sub-network
- Receives configuration data about key range responsibility of the subnet
- Responsible to determine key ranges of each CxB in the subnet with respect to its efficiency factor α, upper key bound key_{up}, and lower key bound key_{lo}

Distributed Context Management Architecture

Primary/Secondary CxB Backup Concept



Px: Primary Broker
Sx: Secondary Broker

- System needs a “backup” solution to be resistant against failures of entities
- Each CxB has a primary and a secondary key range
- Storage of data and key responsibility has to be performed on the primary and secondary CxB
- Redundancy increases system stability

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5. Conclusion

- Resolved design challenges
  - Auto-configuration function has been incorporated
  - Broker architecture has been redesigned as distributed system by exploiting DHTs
  - Full compatibility with mobile brokering subsystems has been achieved
  - Primary/Secondary broker concept ensures a fault-tolerant system
- Proof-of-concept implementations have shown that our architecture fulfills the requirements of scalability, extensibility, and mobility

Thank You for your attention!

Questions?