Prioritized Self-Configuration for Self-Organized Sensor Networks

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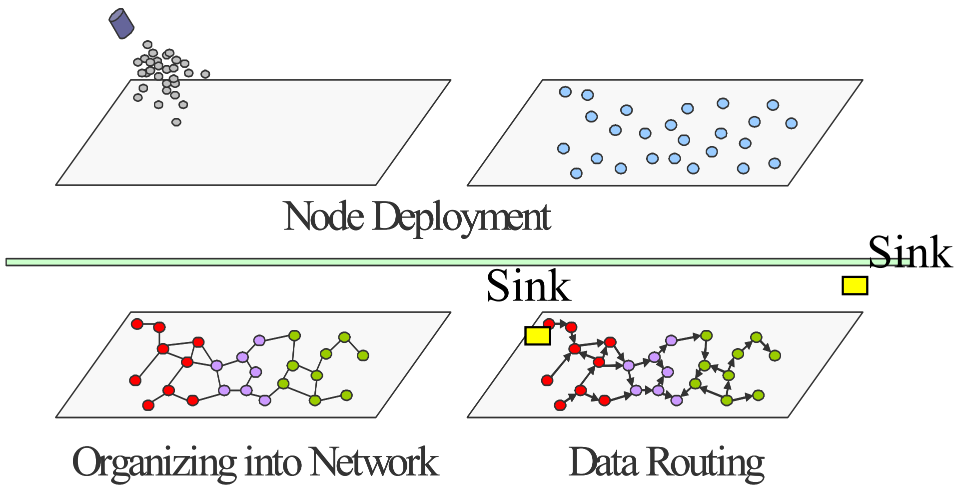
Features of Wireless Sensor Networks

- Energy-efficient communication
  - A sensor node has three functional components: sensing， computing, communication.
  - Power supply from a battery
- Self-organization
  - Free deployment of sensor nodes
  - Self-configuration
  - Self-optimization

An example of self-organized sensor networks

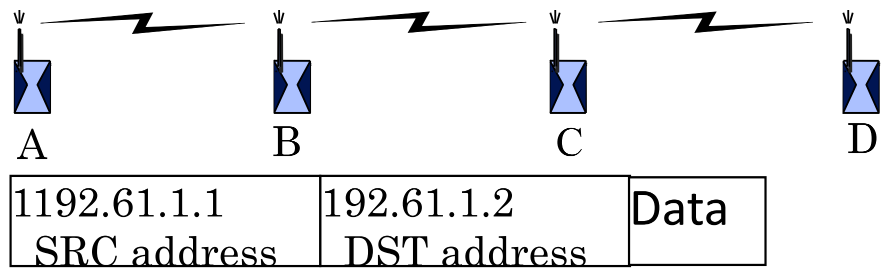


Node Addressing in Sensor Networks

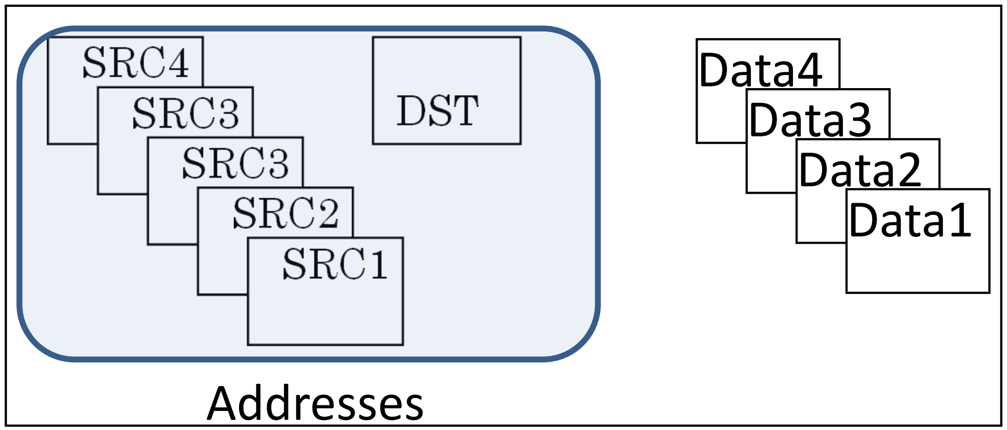
- Functions of node addresses in sensor networks
  - Use as the node identifier (ID) for packet routing
  - Use as the data source ID to distinguish sensing data
  - Use as the alternative of sensor name or data's name

- Requirement of sensor addresses
  - Address auto-configuration
  - Energy efficiency

An example of sensor data reports



An example of aggregated data reports



Conventional Addressing Approaches

Addressing in the Internet

- Address representations in the Internet Protocol
  - IP address
    - Global Unique
    - 32 bits IPv4 address, 128bits IPv6 address
- Address Configuration in the Internet Protocols
  - Manual setup
  - Dynamic address configuration, Such as DHCP

Addressing in the MANET (Mobile Ad hoc Network)

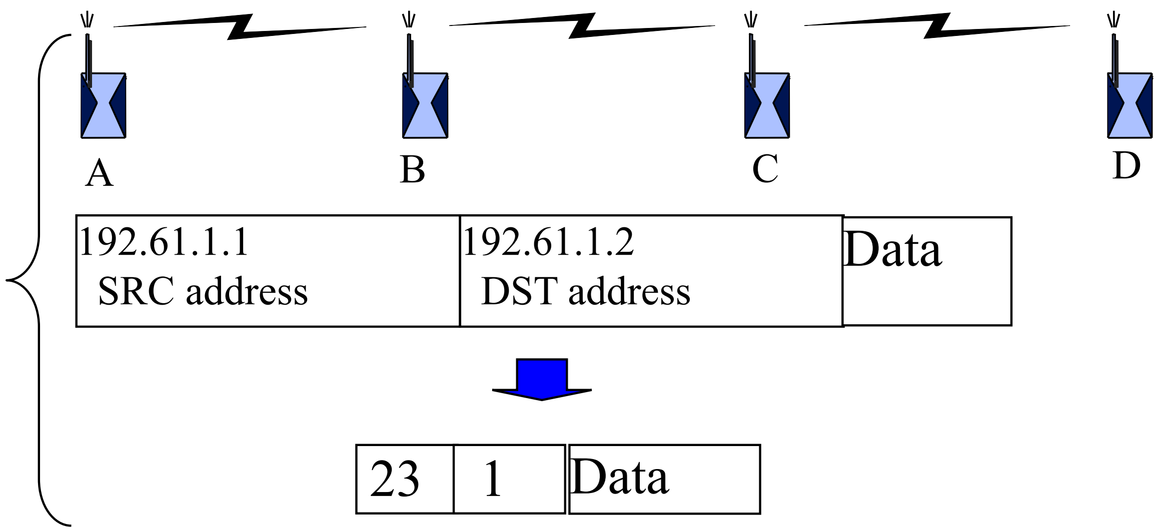
- Network-layer address
  - IP Address
- Address Configuration:
  - Manual setup of address
  - Auto-configuration
  - Fundamental approach: DAD (Duplicate address detection)
    - Dealing with Network partition and merge
  - Routing based configuration

Desired Address Representation in Sensor Networks

- Smallest address size
  - Avoid using long-size global unique addresses

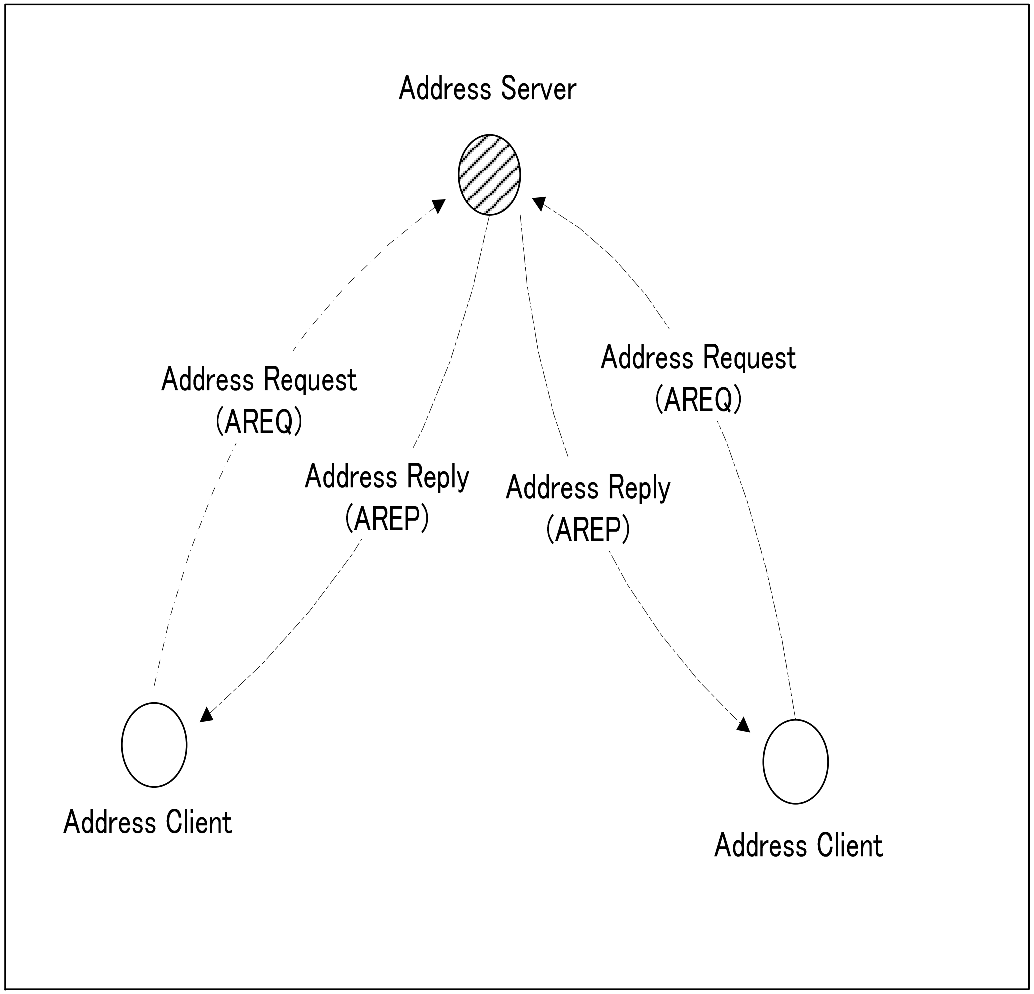
    e.g., IPv4 with 32bits; IPv6 with128 bits

An example of sensor data reports



Dynamic Server-client Based Configuration

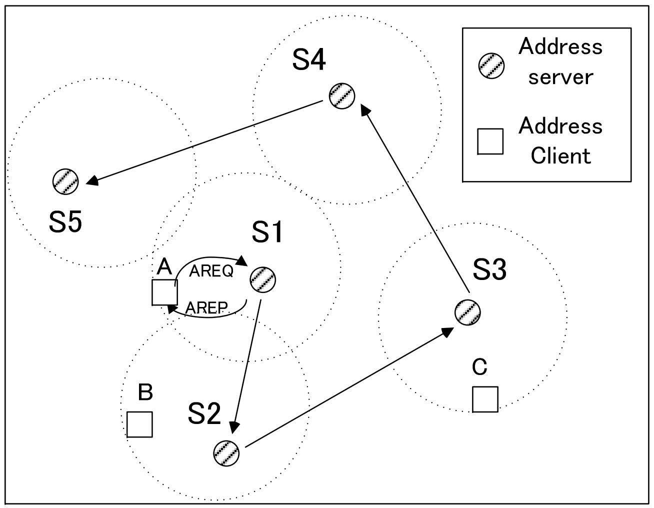
- Initially, an address server is randomly selected.
- The role of address server is to assign address to sensors that request addresses
- The address clients that request addresses send Address Request (AREQ) message to the server to ask for addresses.
- The address serve responses to each AREQ by assigning the address client with a unique address, which is included in the Address Reply(AREP) message.



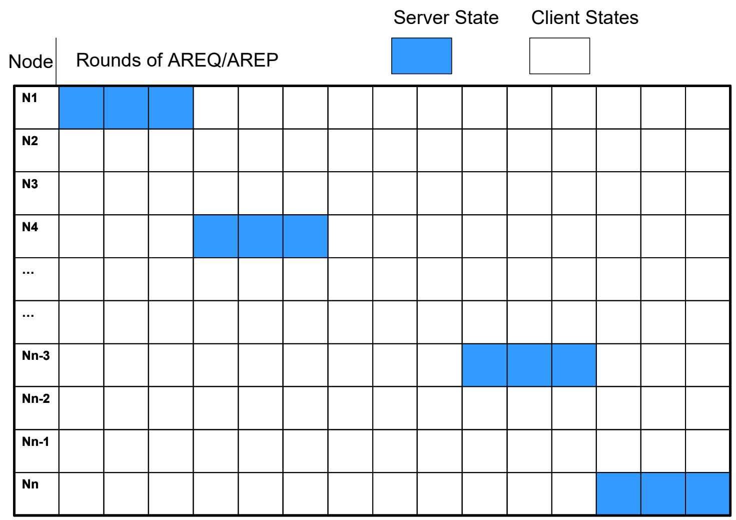
Automaticaly selected address server

Dynamic Roles of Address Server

- To balance the energy consumption, the role of address server is rotated around sensors in the network.
- This is realized by setting a limited server term at each address server.



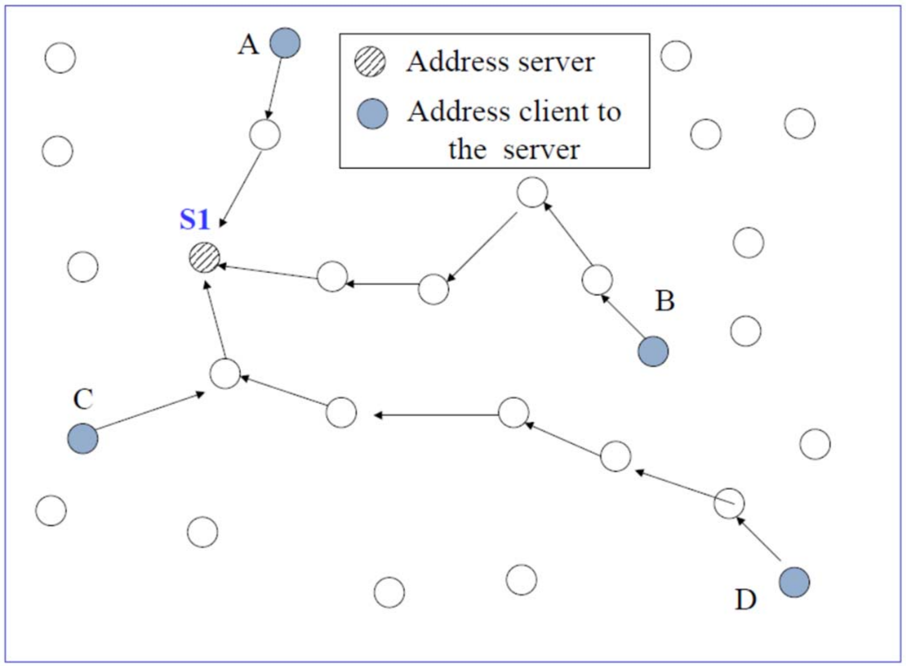
Address server rotation



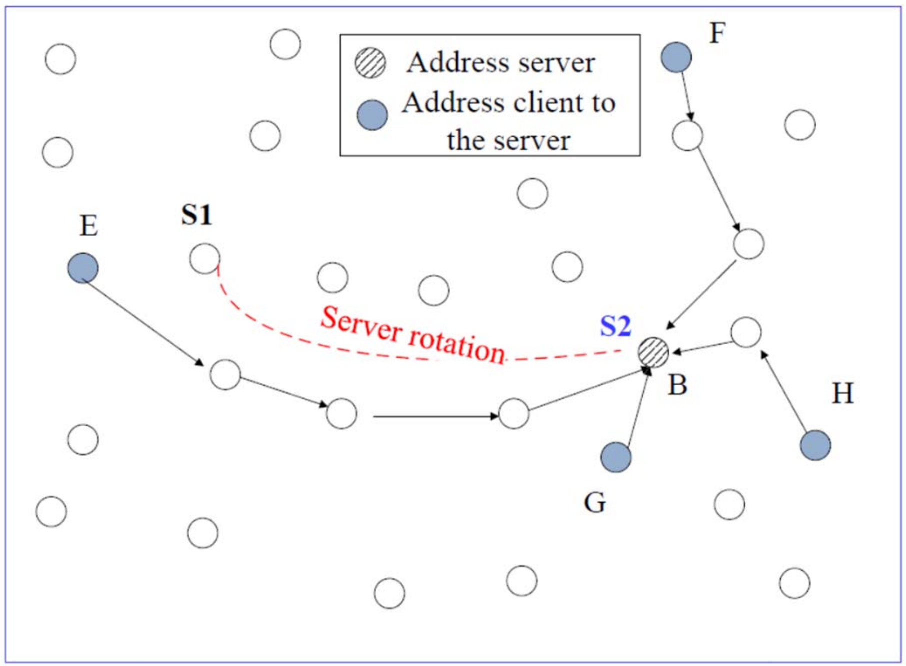
Server term control

Configuration Distance Problem

- Problems of long topological distance between sensor client and server
  - Large energy consumption
  - Configuration latency



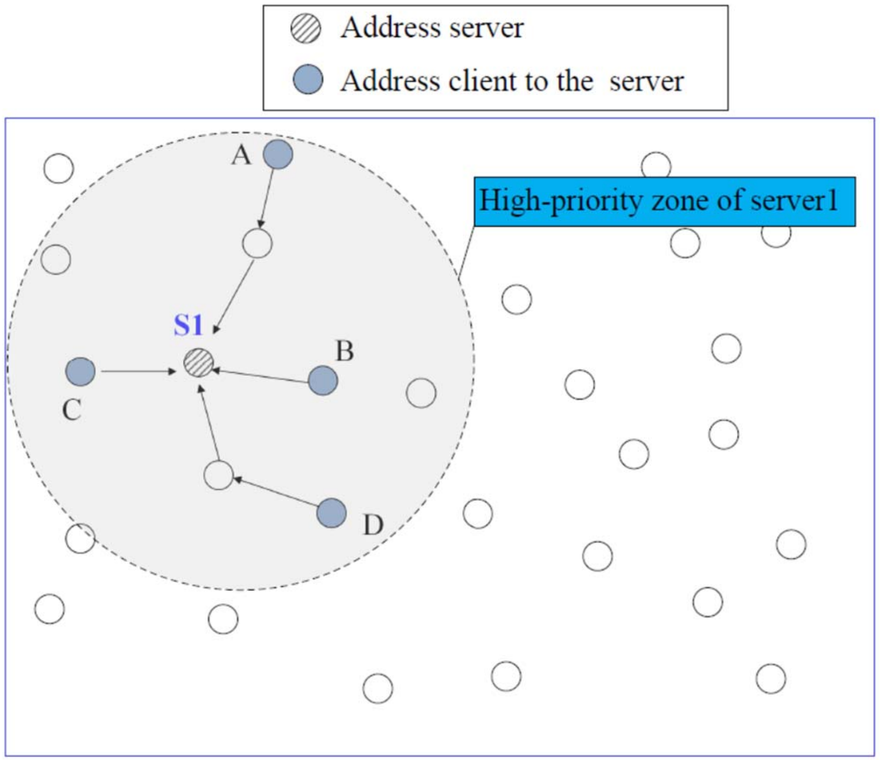
Address configuration with server 1



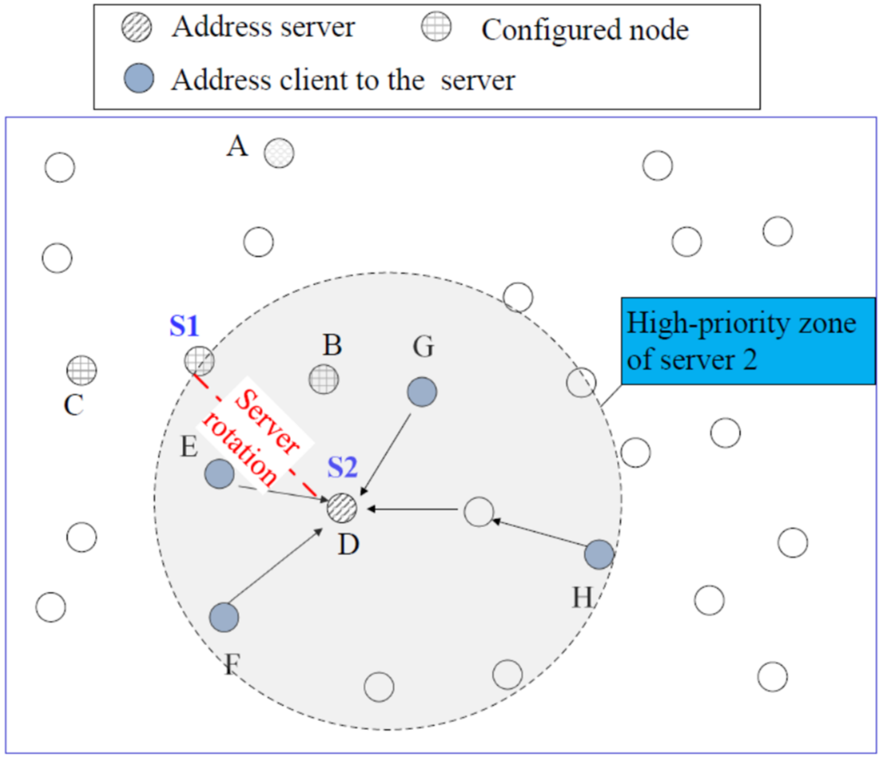
Address configuration with server 2

Method: Dynamic Priority-Zone Based Configuration Control

- Priority zone setup
  - Sensor nodes near the address server have higher priority to get their addresses configured by the server.
  - Reduce energy consumption, network traffic, and configuration latency.



Address configuration with server1



Address configuration with server 2

Algorithm of Prioritized Configuration Control

Algorithm 1 Prioritized configuration control at each sensor node.

Input: network topology, Timepool1, TimePool2

$Timepool2 \leftarrow \frac{Timepool1}{K}$

if $ConfigurationState == 0$ **then**

  if $InHighPriorityState == 1$ **then**

    $ConfigSeat \leftarrow Random(0, Timepool2)$

  end if

  if $InHighPriorityState == 0$ **then**

    $ConfigSeat \leftarrow Random(0, Timepool1)$

  end if

  if $ConfigurationSeat == HitNum$ **then**

    Issue a request to the address server

  end if

  if

    Obtaining an address from the server **then**

    ConfigurationState $\leftarrow 1$

  end if

end if

The configuration request at each node may have a different priority in terms of topological distance between the sensor client and the address server.

Server Term Control

Algorithm 2 Serving term control.

Data Input: Serving term, network topology
for $i = 1 \rightarrow N$ **do**
    ConfigurationState[i] $\leftarrow 0$
end for
ServerID1 $\leftarrow RandomlySelectedID$
ConfigurationFinishState $\leftarrow 0$
while $ConfigurationFinshState == 0$ **do**
    if $ServerRotationState == 0$ **then**
        Configuration of the selected nodes
        if $ServingCount == Term$ **then**
            $ServerRotationState \leftarrow 1$
            $LastID \leftarrow LastConfiguredID$
            $NextServerID \leftarrow LastID$
        end if
        Update ConfigurationFinshState
        Update server rotation state
    end if
end while

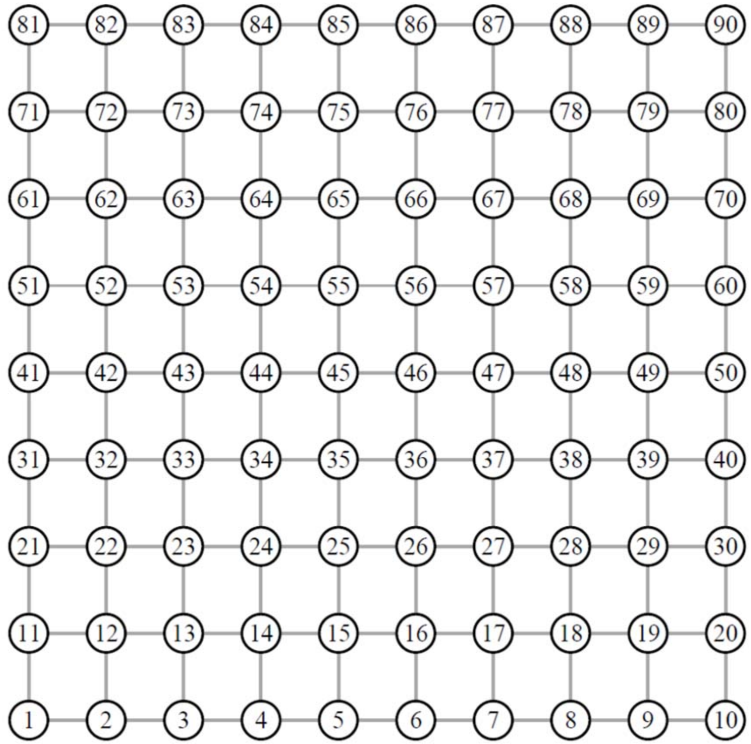
Server roles are rotated among Sensors with the server-term control.

Simulation Evaluation

Simulation Setup

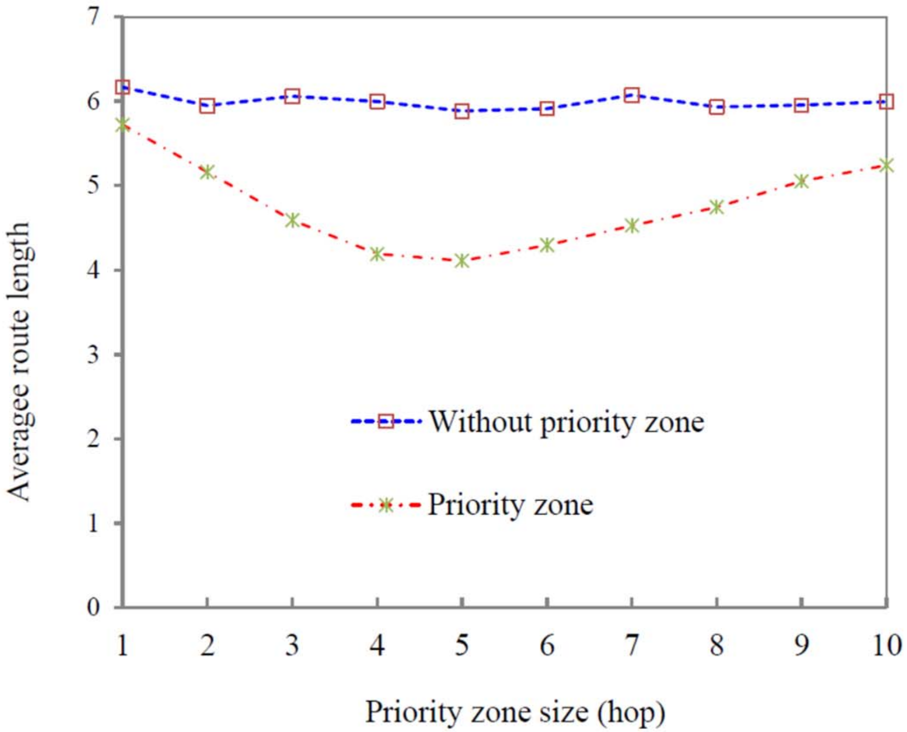
Basic Simulation Setup	
Parameters	Setup
Number of nodes in the network	90, 160
Server term	10
Communication range	10 m
Timepool1	200
Timepool2	20
Rounds of simulation	50

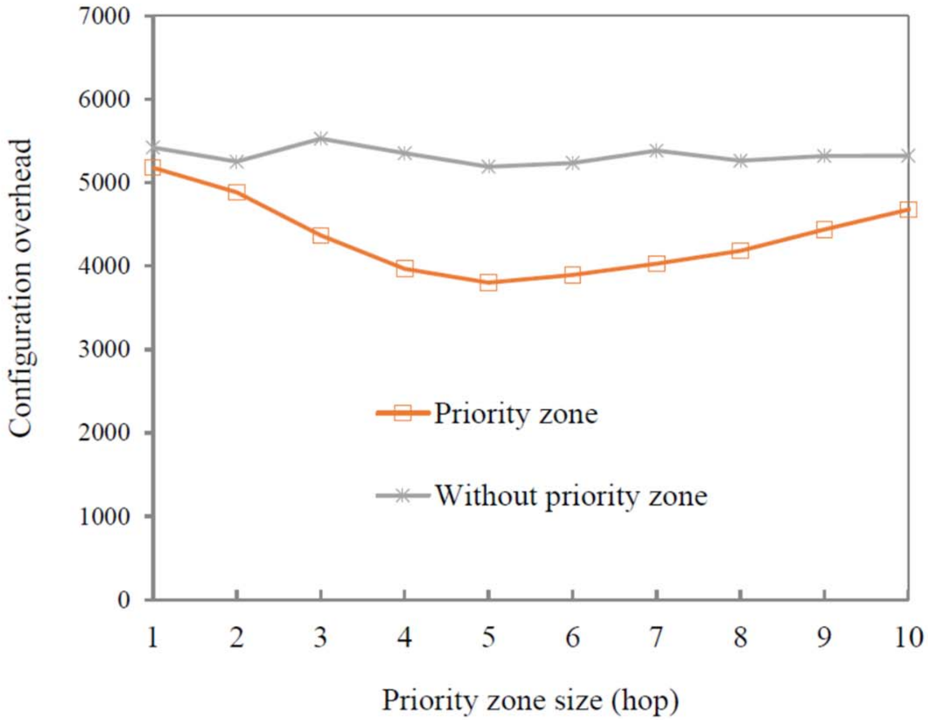
Topology of evaluation scenario of 90 nodes



- Evaluation scenarios
  - Scenario1: 90 nodes
  - Scenario2: 160 nodes
- Two methods are examined:
  - Dynamic-server based configuration;
  - the proposed scheme of prioritized configuration.

Numerical Results



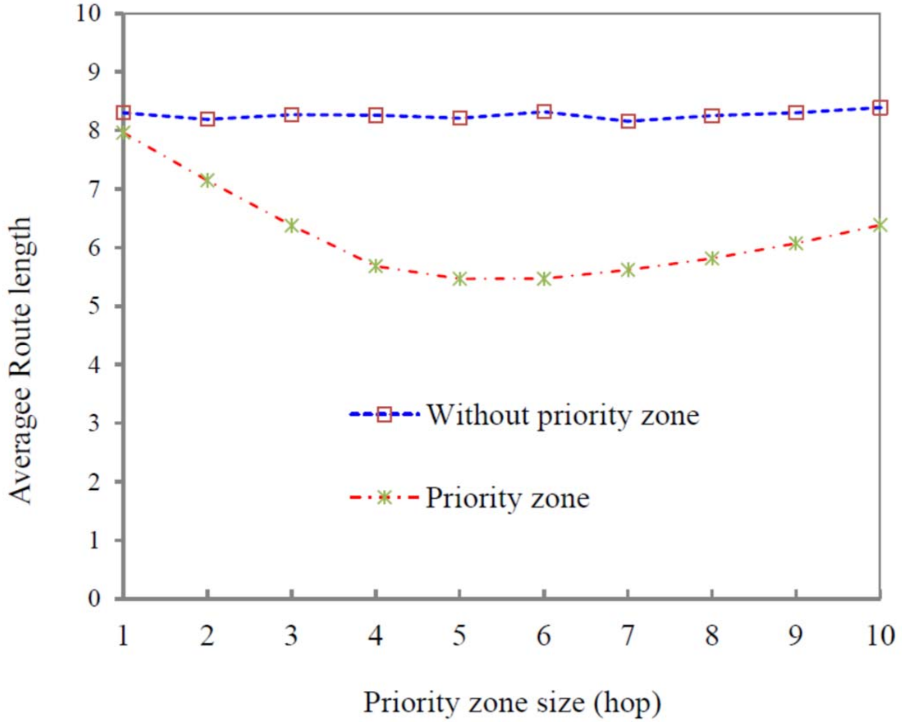


Average route length in the network with 90 nodes

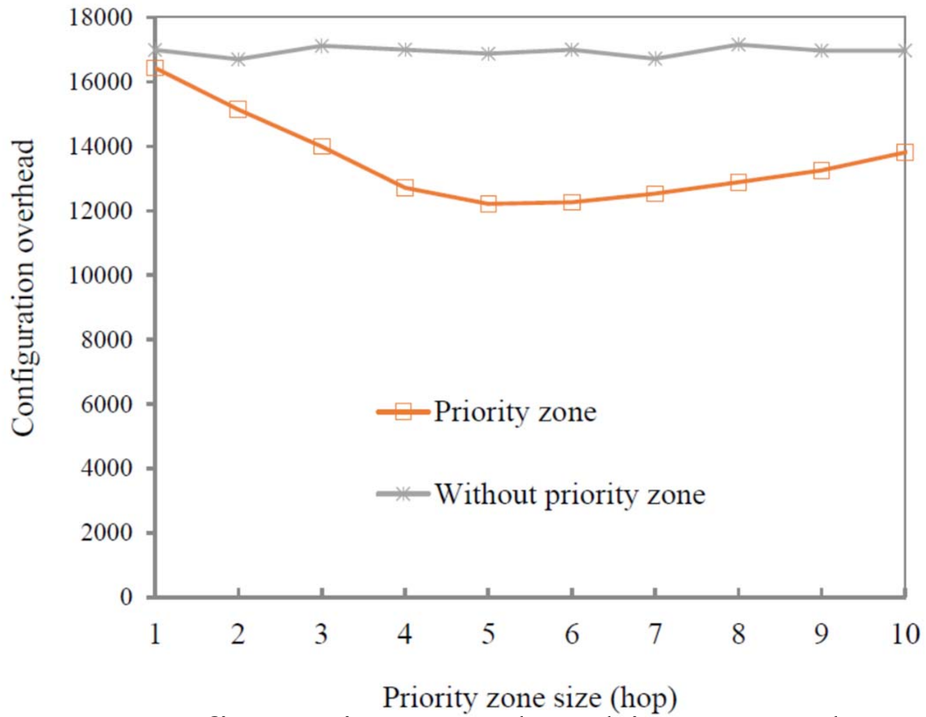
Configuration overhead in network with 90 nodes

- The proposed method enables enables a reduction of up to 30 percent in configuration distance (route length).
- The proposed method also enables a reduction of up to 27 percent in configuration overhead.

Numerical Results



Average route length in network with 160 nodes



Configuration overhead in network with 160 nodes

- The proposed method enables enables a reduction of up to 33 percent in configuration distance (route length).
- The proposed method also enables a reduction of up to 28 percent in configuration overhead.

Conclusion

- This paper addressed the configuration distance problem in auto-configuration of small-size addresses in a self-organized WSN.

- We proposed a prioritized configuration method that
  - employs configuration-priority control in the address request at each sensor client
  - utilizes the spatial-temporal association between address clients and the server.

- The evaluation results show the effectiveness of the proposed method
  - Reducing the configuration distance
  - Reducing the configuration overhead.
  - We find that there is an optimal setup of high-priority zone for the configuration to enable the shortest configuration distance.