THE DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING 計算機科學及工程學系

A Synergy of the Wireless Sensor Network and the Data Center System

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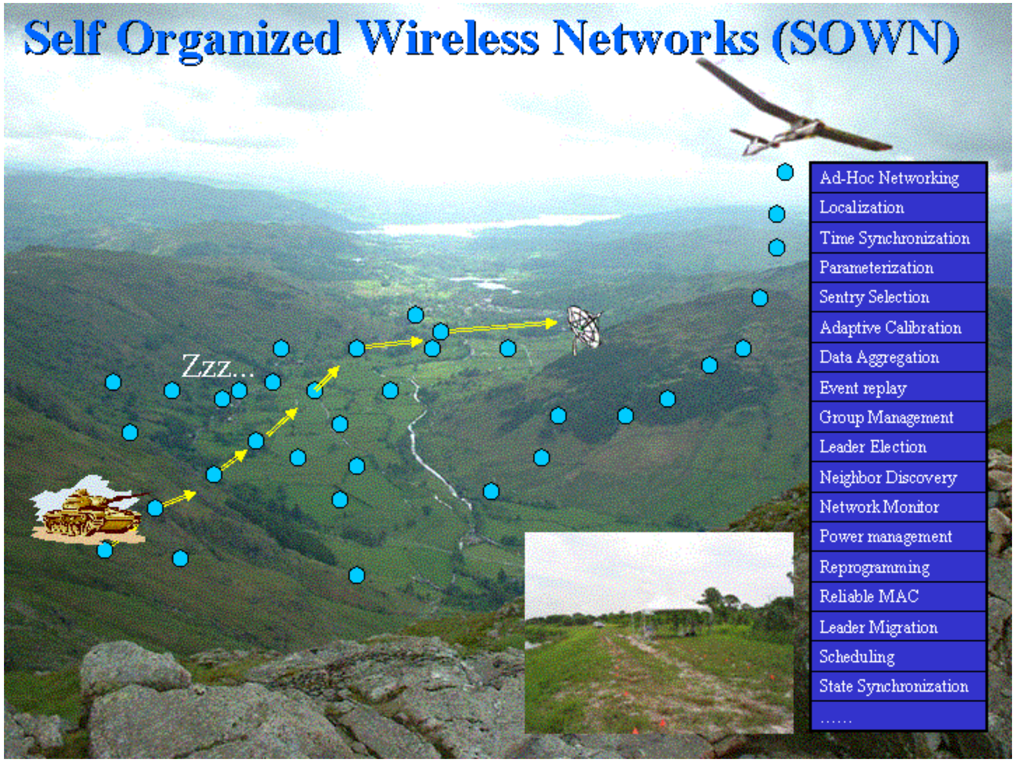
Data Center vs. Sensornet

- Both distributed, dense, scalable
  - 300 nodes in VigilNet, hundreds in GreenOrbs, 1000+ in ExScal



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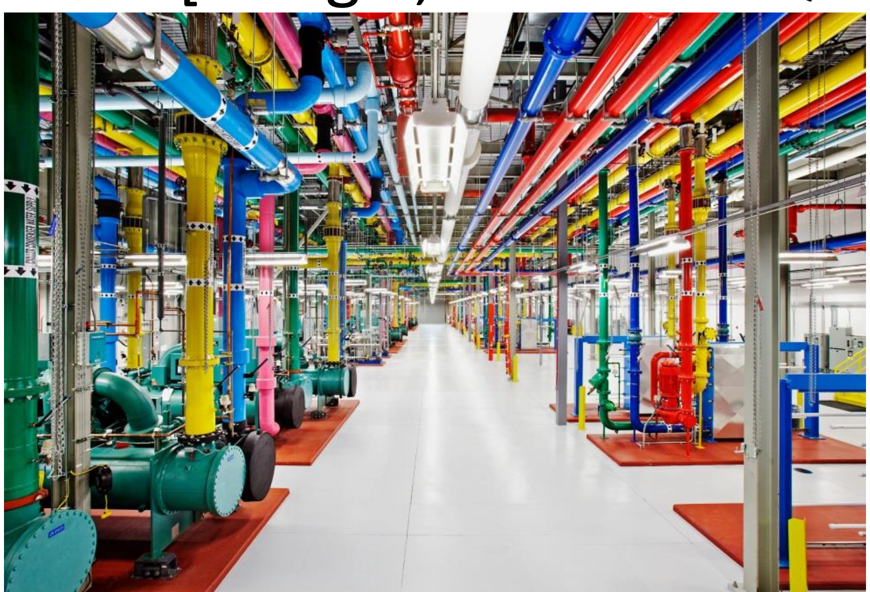
  - Thousands of compute servers organized in racks [Google, Microsoft Quincy]



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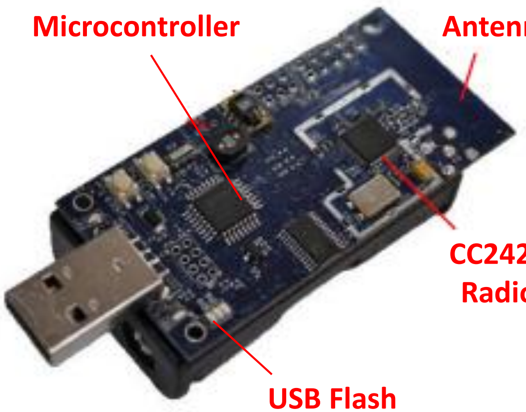
- Low-end and high-end of computation
  - Limited computing resource on each sensor node
  - Abundant computing resources on rack servers

Related Work

- Sensornet in data centers
  - “Cool” scheduling [USENIX ‘05]
  - RACNet [SenSys ‘09]
  - Thermocast [KDD ‘11]



- The combined computational and networking capability of a sensornet enables it to interact with compute clusters in a more sophisticated way

Cluster-Area Sensor Network

- CASN as a complementary solution
  - To improve the cluster management
  - To enhance the operational security

- Cluster-wide command dissemination

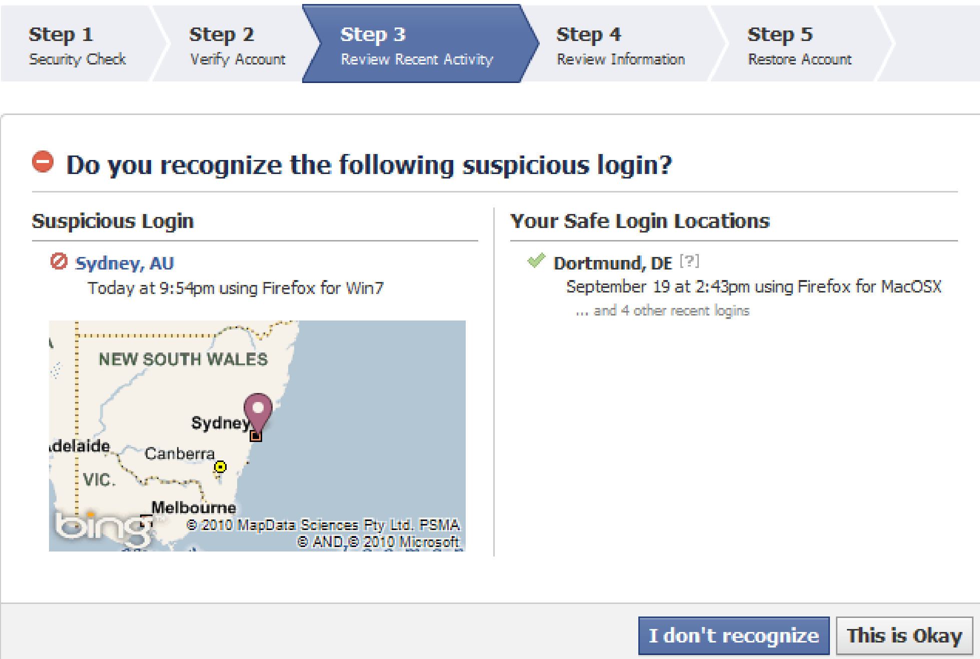
- Verification of server's physical presence

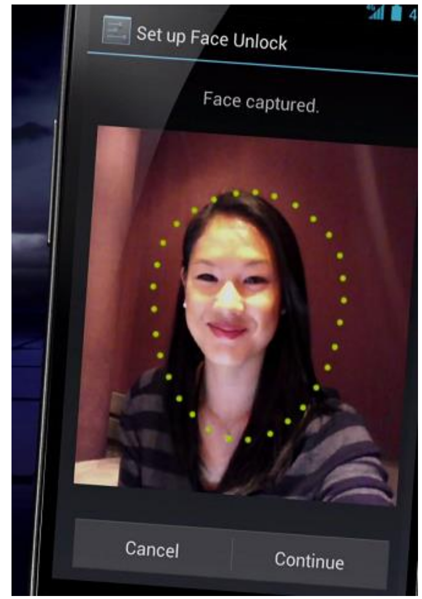
Management in Data Centers

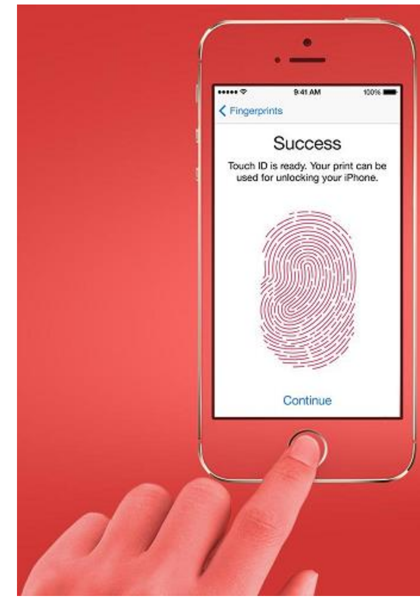
- Software reprogramming on compute servers
  - System settings, configuration files, software upgrade
  - Usually performed on a management station
  - Require certain manual operations

- Why not wirelessly broadcast commands and small files via a sensornet?
  - Wireless as a convenient and flexible broadcast medium

Security Hints







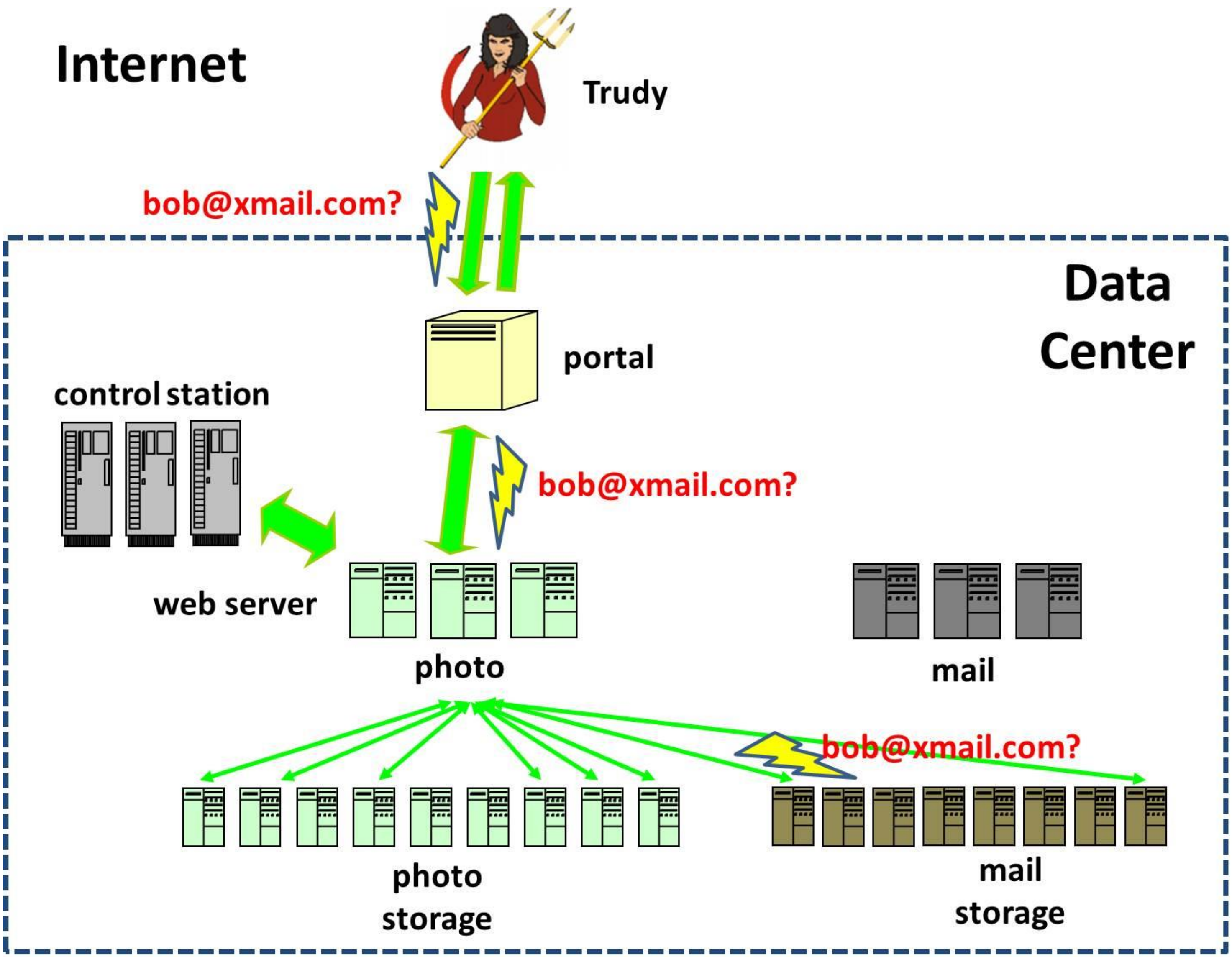
Two-step verification adds an extra layer of protection to your account. Whenever you sign in to the Dropbox website or link a new device, you'll need to enter both your password and a security code sent to your mobile phone.

Security in Data Centers

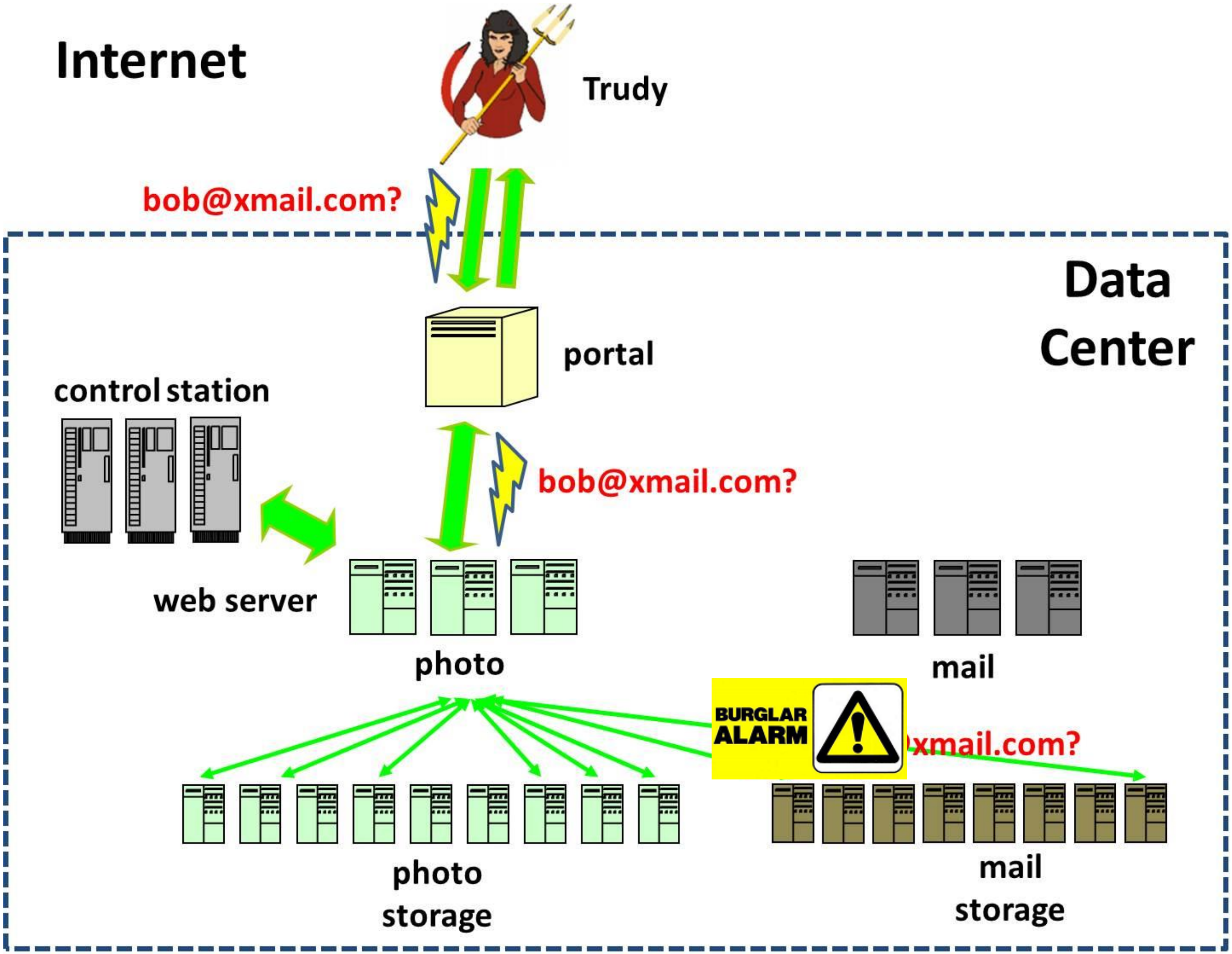
- Existing cryptologic methods do not entirely ensure the operational security of data centers
  - User account leakage at *Yahoo!*, *Sony PlayStation Network* and *Qriocity*
  - Need additional measures for security monitoring

- New security hint: **servers' physical presence**
  - Servers in data centers usually serve different roles (i.e. management, web agent, mail agent, storage)
  - Alarm triggered upon request from strange roles

Access Path Verification

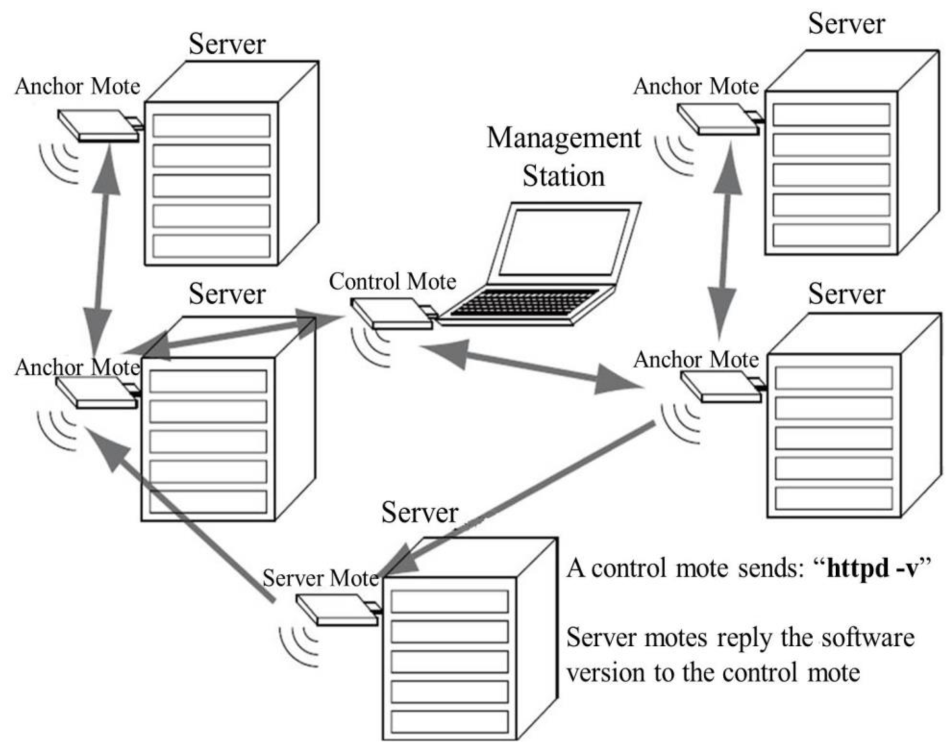


Access Path Verification



CASN Architecture

- System components
  – Sensor network
  – Compute servers
- Three types of motes
  – Control motes
  – Anchor motes
  – Server motes

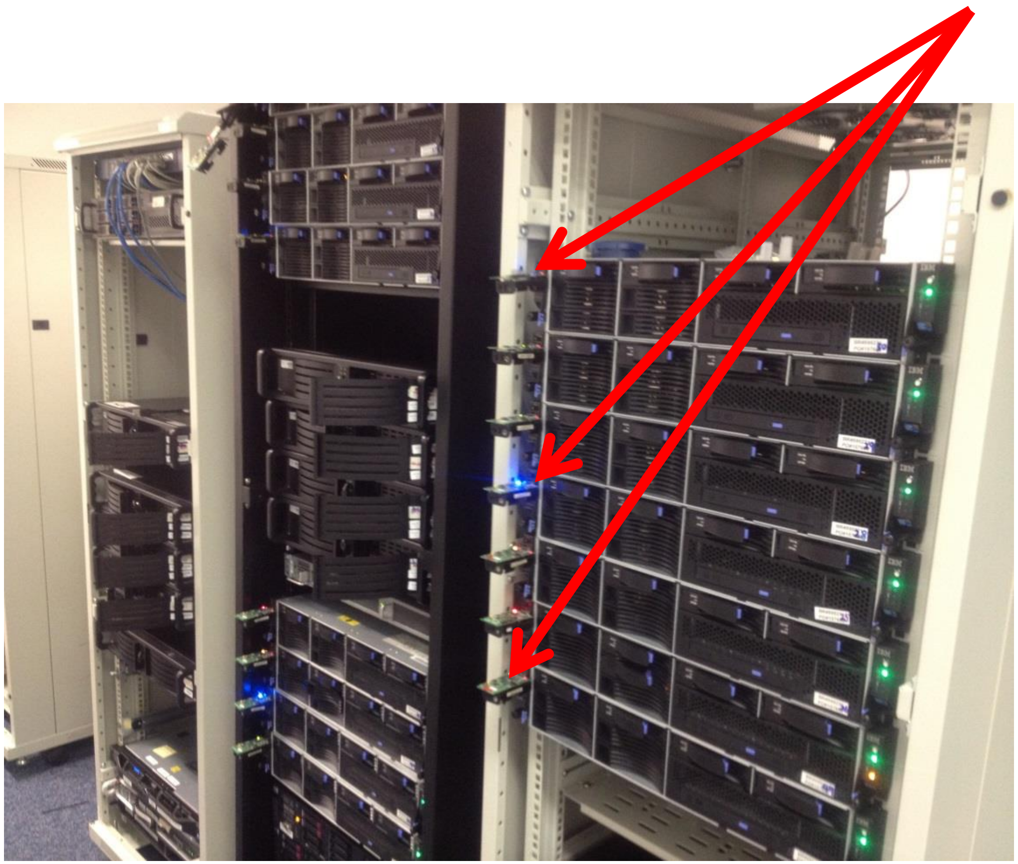


Prototype Implementation

A prototype of CASN consisting of 1 control mote and 4 anchor motes (Telos B) in a research cluster

Prototype Implementation

motes attached to servers via USB interfaces



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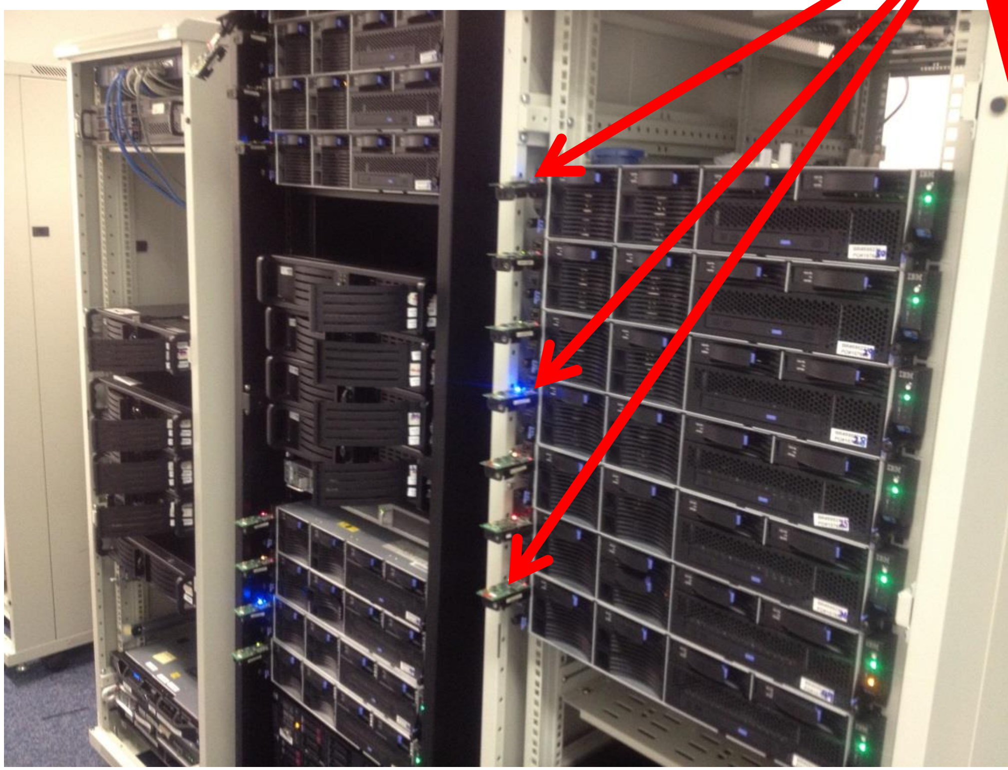

Cluster-Area Sensor Network

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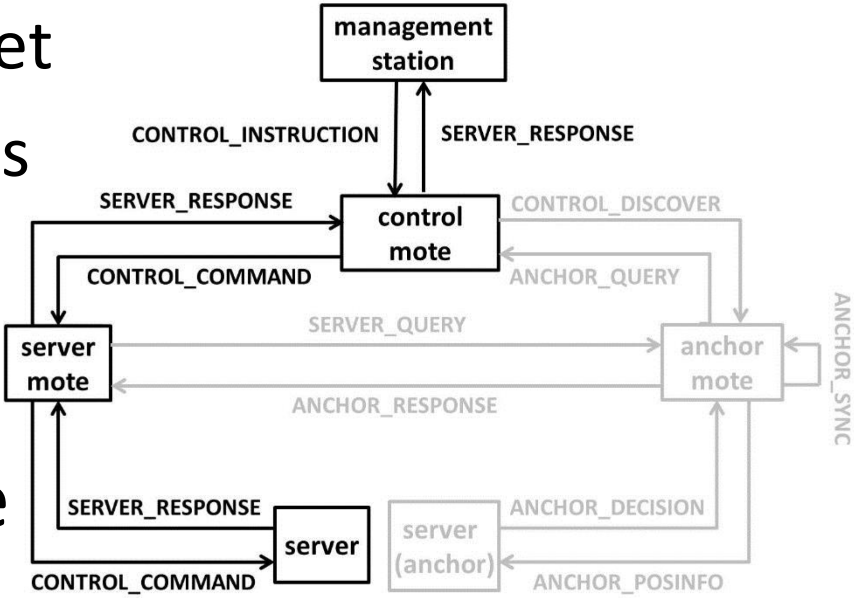
Command Dissemination

- Workflow of command dissemination
  – Issued from the management station
  – Forwarded to the control mote
  – Broadcasted via sensornet
  – Received by server motes
  – Executed on servers

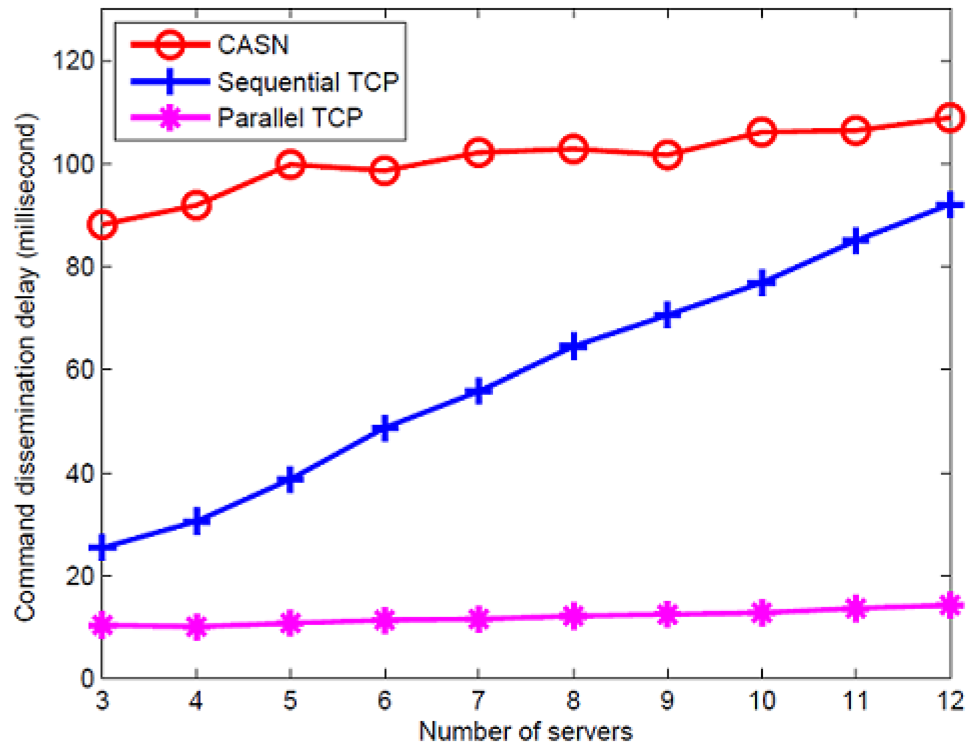


- Command-line interface

Command Dissemination Delay

- To evaluate the round-trip delay of command dissemination to a number of servers across three racks

- Results
  - Scalable broadcast via sensornet
  - Stable delay



Cluster-Area Sensor Network

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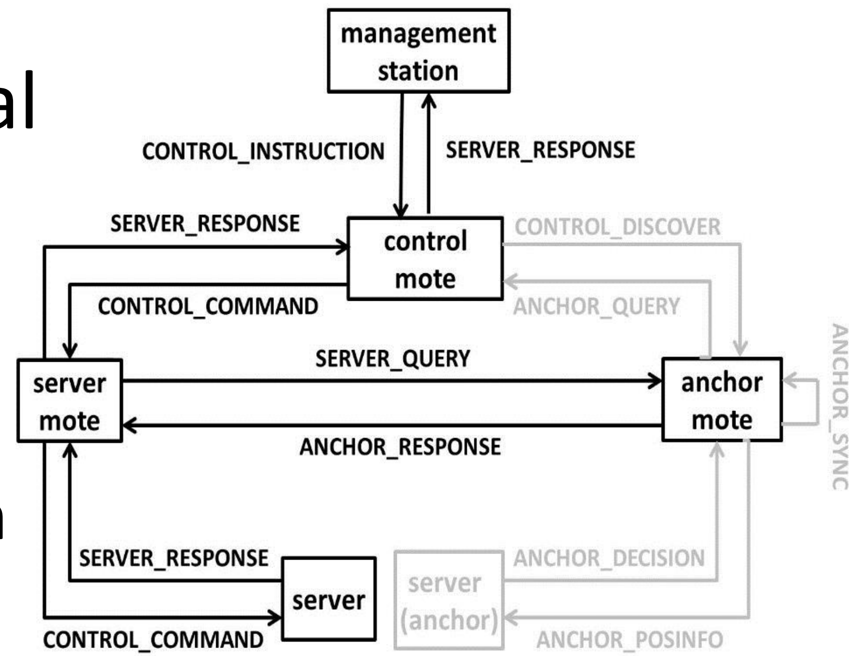
Verification of Physical Presence

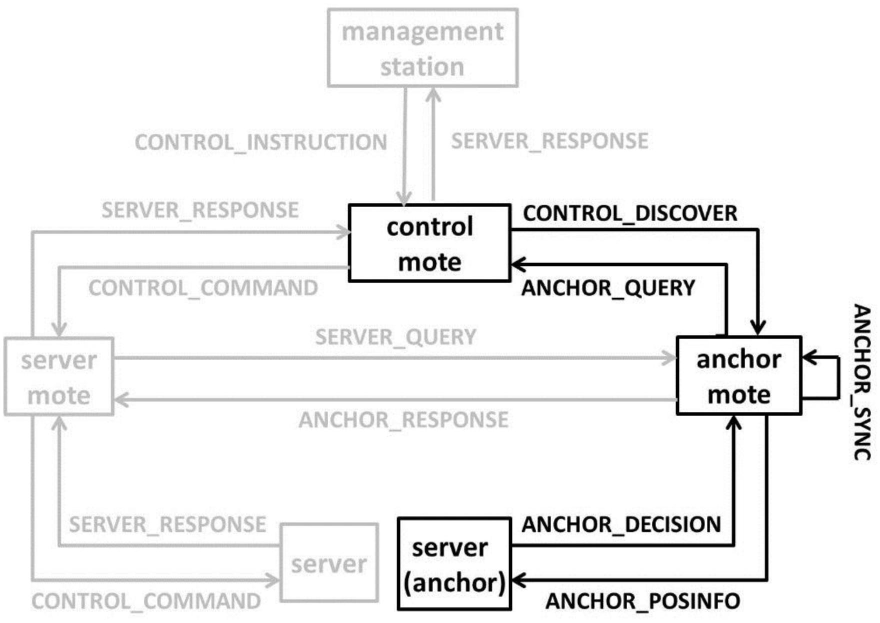
- Operations in data center are yet to be secure
  - Example: impersonating the management station

- Example: verify the physical location of a control mote
  - Before execution, server motes query anchor motes for the legitimacy of certain control mote



Localizing Control Motes

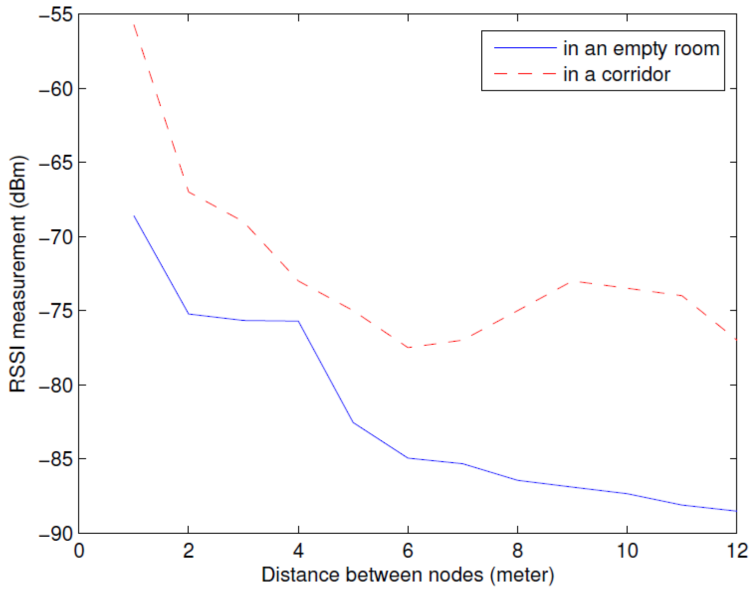
- Workflow of physical localization
  - Passive discovery: anchor motes periodically query the location of control motes
  - Active discovery: control mote initiates discovery upon its arrival
  - Anchor motes together localize a control mote to determine its legitimacy
- Suffice with 4 anchors



Radio-based Localization

- Coarse-grained radio-based localization
  - Suffice even at 5-meter precision
  - Inefficacy of RSSI-based ranging approach

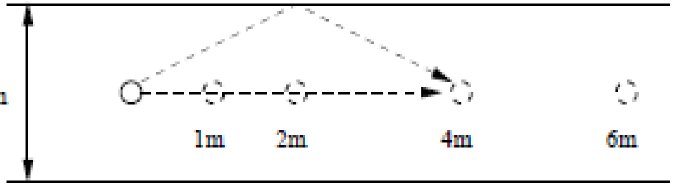
$$P(d) = P(d_0) - 10n \log(\frac{d}{d_0})$$



- Necessity for empirical RSSI modeling in a data center environment

Empirical Localization Model

- Cope with the multipath effect by considering indirect signals



$$P(d) = P(d_0) - 10n\log\left(\frac{\sum_{i=1}^{k} r_i d_i}{d_0}\right)$$

  - $\boldsymbol{R} = [r_1\ r_2\ \ldots\ r_k]$ as the amplitude coefficients of signal components
  - $\boldsymbol{D} = [d_1\ d_2\ \ldots\ d_k]$ as discretized distances of signal components

- Rician distribution used to model amplitudes of indirect signals

$$R(x|\gamma,\sigma) = \frac{x}{\sigma} e^{\frac{-(x^2+\sigma^2)}{2\sigma^2}} I_0\left(\frac{x\gamma}{\sigma^2}\right)$$

Probabilistic Ranging

- Solving ***R*** in $\boldsymbol{R} * \boldsymbol{D} = d_0 * 10^{\frac{P(d_0)-P(d)}{10n}}$
  - Consider only the 5 shortest reflected signals
  - d_{AB} as the distance between the transmitter A and receiver B (i.e. 2 meters)

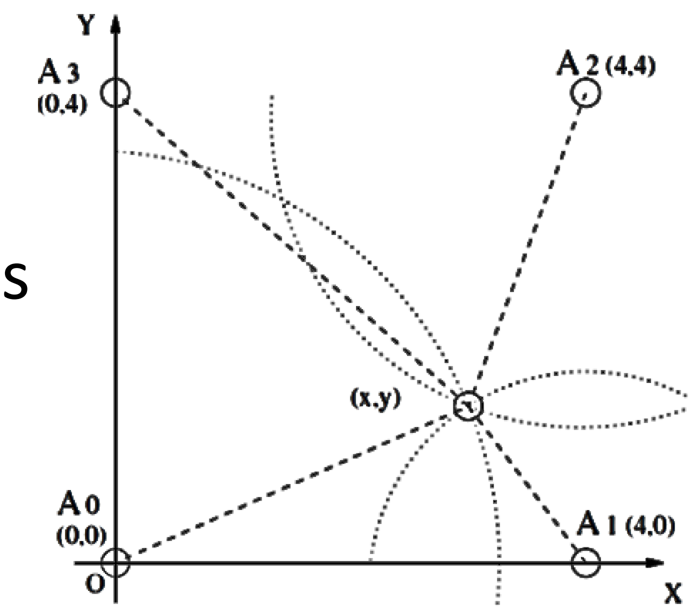
$$r_i = \begin{cases} 0 & if\ d_i < d_{AB}\ or\ d_i - d_{AB} \geq 2 \\ 1 & if\ d_i = d_{AB} \\ a_i * R(d_i - d_{AB}) & if\ d_i > d_{AB}\ and\ d_i - d_{AB} < 2 \end{cases}$$

- Localization: after obtaining the probabilistic ranging results, compute the most plausible location using trilateration

Reduce Computation Cost

- Computationally costly for all possible cases
  - In total K^H cases for *H* RSSI measurements per transmission, give that each maps to *K* **R**s

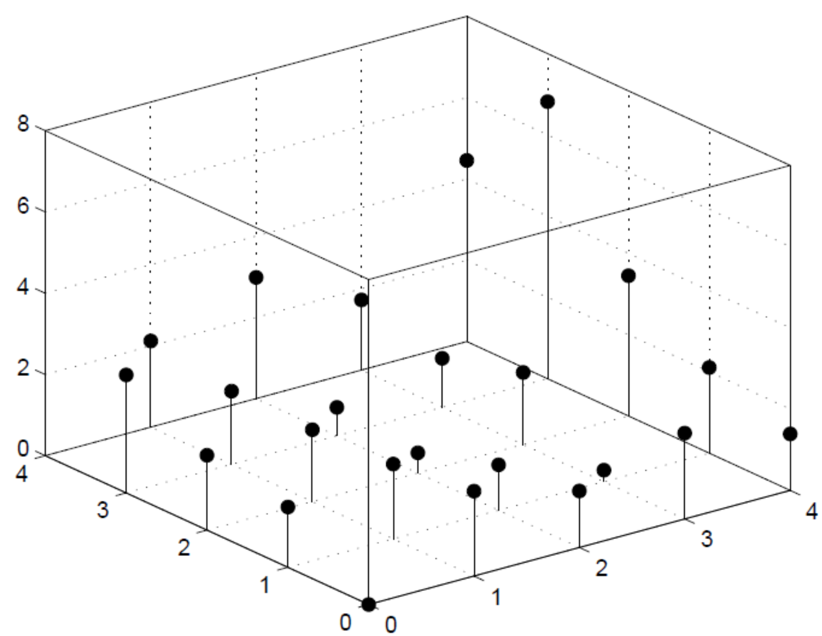
- Reduce computation cost by
  - Narrowing down distances by applying geometric constraints
  - Utilizing the known distances between anchors



Localization Accuracy

- Evaluate the localization accuracy in a 4m x 4m square field defined by A_0, A_1, A_2, A_3
  - Localization error *e* = $\sqrt{(x' - x)^2 + (y' - y)^2}$

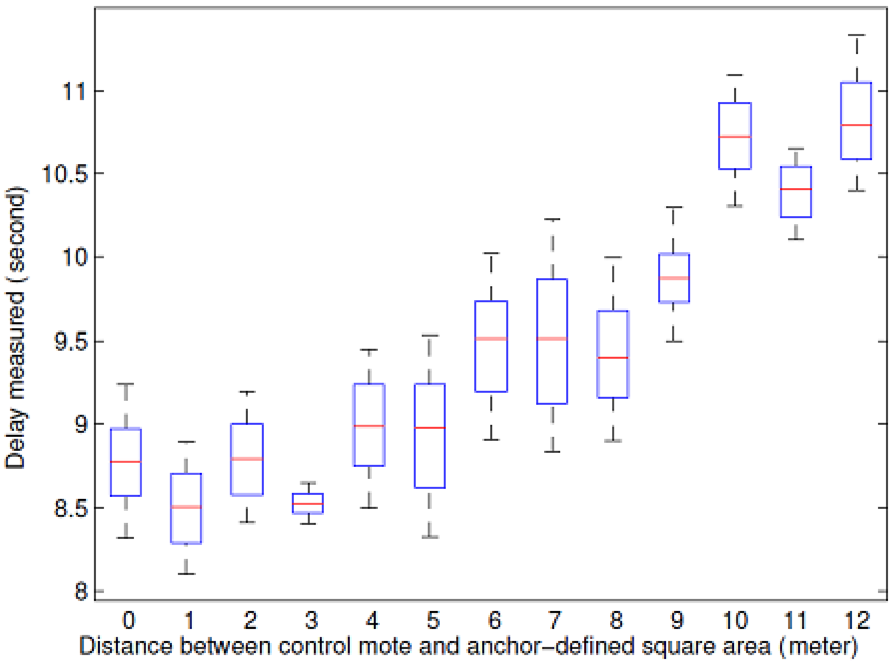
- Results
  - 88% of localization errors within 5 meters
  - Errors for positions inside the square within 2 meters



Localization Delay

- To evaluate the localization delay by varying the distance between a control and an anchor mote inside the 4m x 4m square field

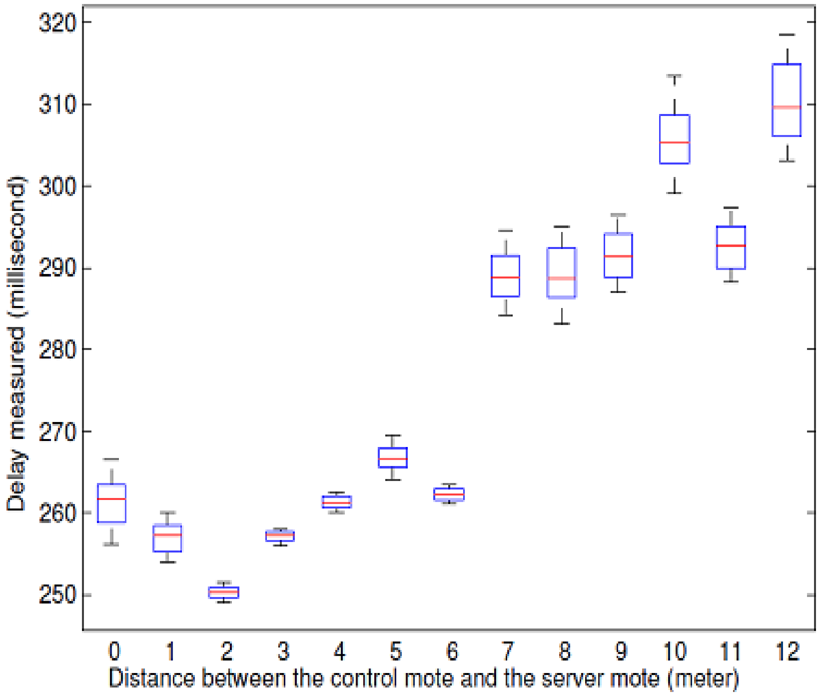
- Results
  - Overall 8-12 seconds
  - Small variation
  - Acceptable with 30-sec localizing period



Reprogramming Delay of CASN

- Reprogramming delay: command dissemination delay + physical verification delay

- Results
  - Less than 300 milliseconds with distance closer than 10 meters
  - Low enough for effective command dissemination



Summary

- We design and implement a cluster-area sensor network in a data center
  - Wireless cluster-wide command dissemination
  - Empirical localization for verification of server’s physical presence
- Future work
  - CASN with fingerprint-based localization
  - CASN in geographically distributed data centers

Q&A

Thank You!

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