# Dynamically Partitioning Applications between Weak Devices and Clouds

Mobile Cloud Computing and Services Workshop 2010

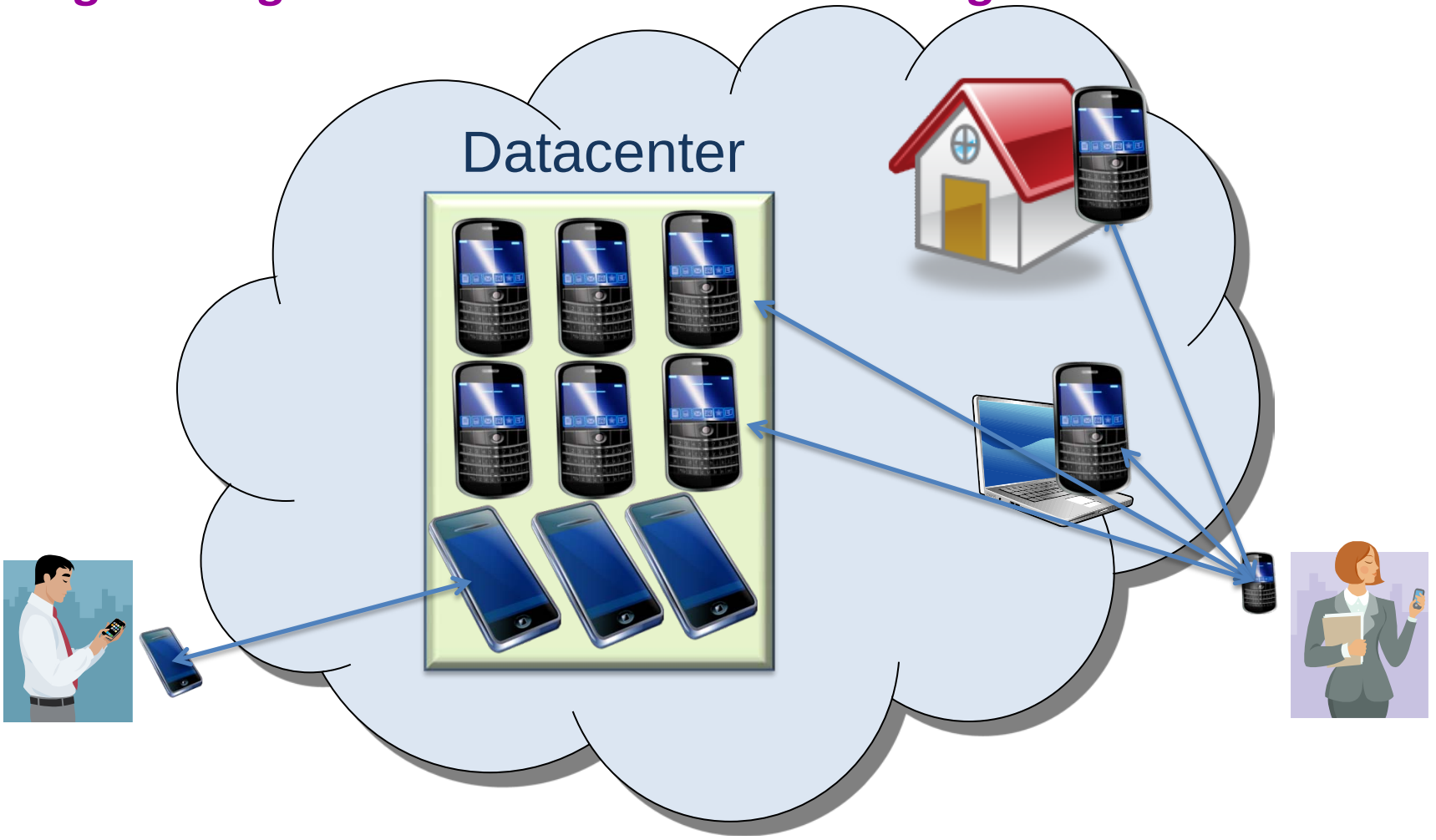
*Byung-Gon Chun*, Petros Maniatis
Intel Labs Berkeley

# Weak devices

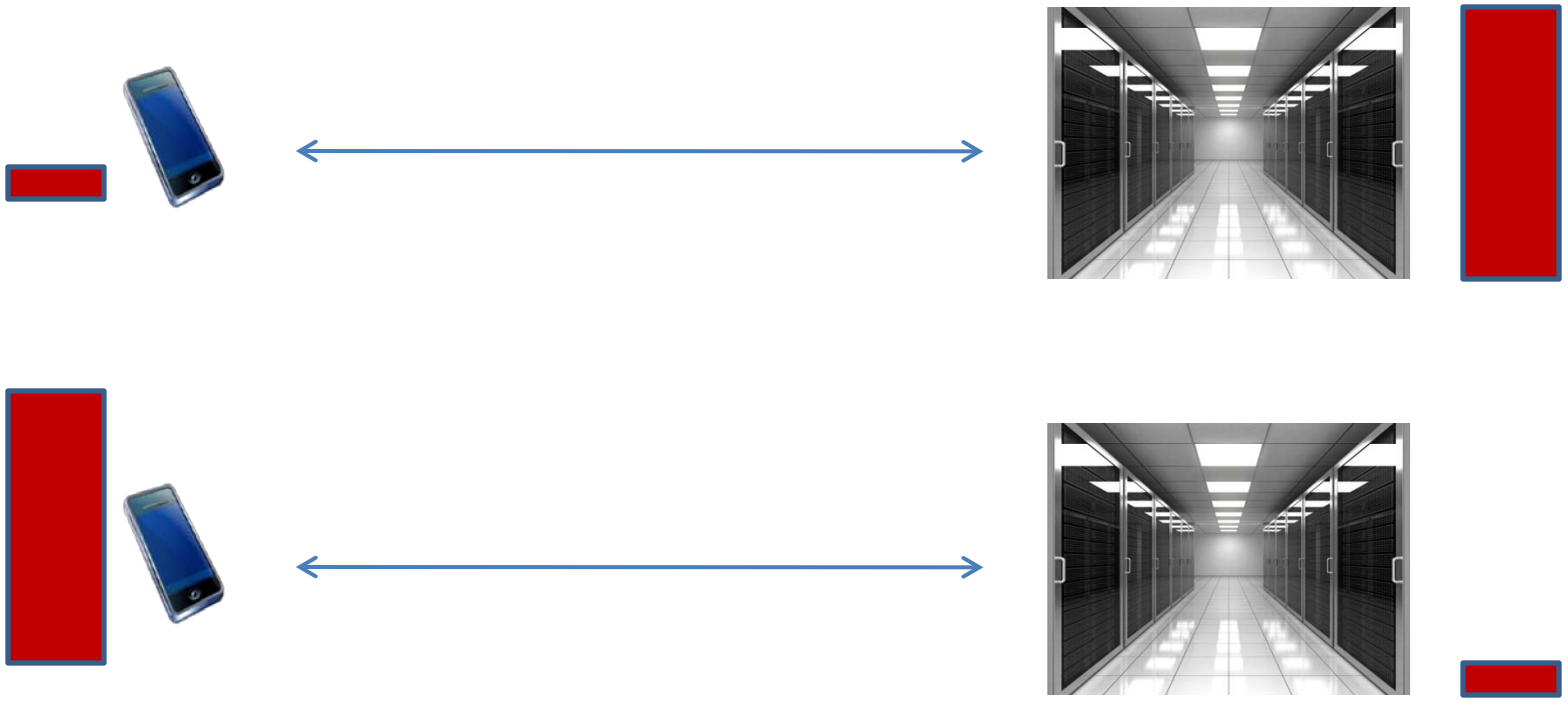
- Weak devices
  - » Smartphones
  - » Netbooks/Tablets
  - » Mobile Internet Devices
  - » Embedded devices
  - » Vehicles
  - » TVs
  - » …
- Applications
  - » Facebook, Twitter
  - » Video, photo viewing/editing
  - » Finances
  - » Games
  - » Rich media
  - » …

# CloneCloud (HotOS 2009)

## Augmenting mobile device execution through cloud execution



# Current applications are statically partitioned



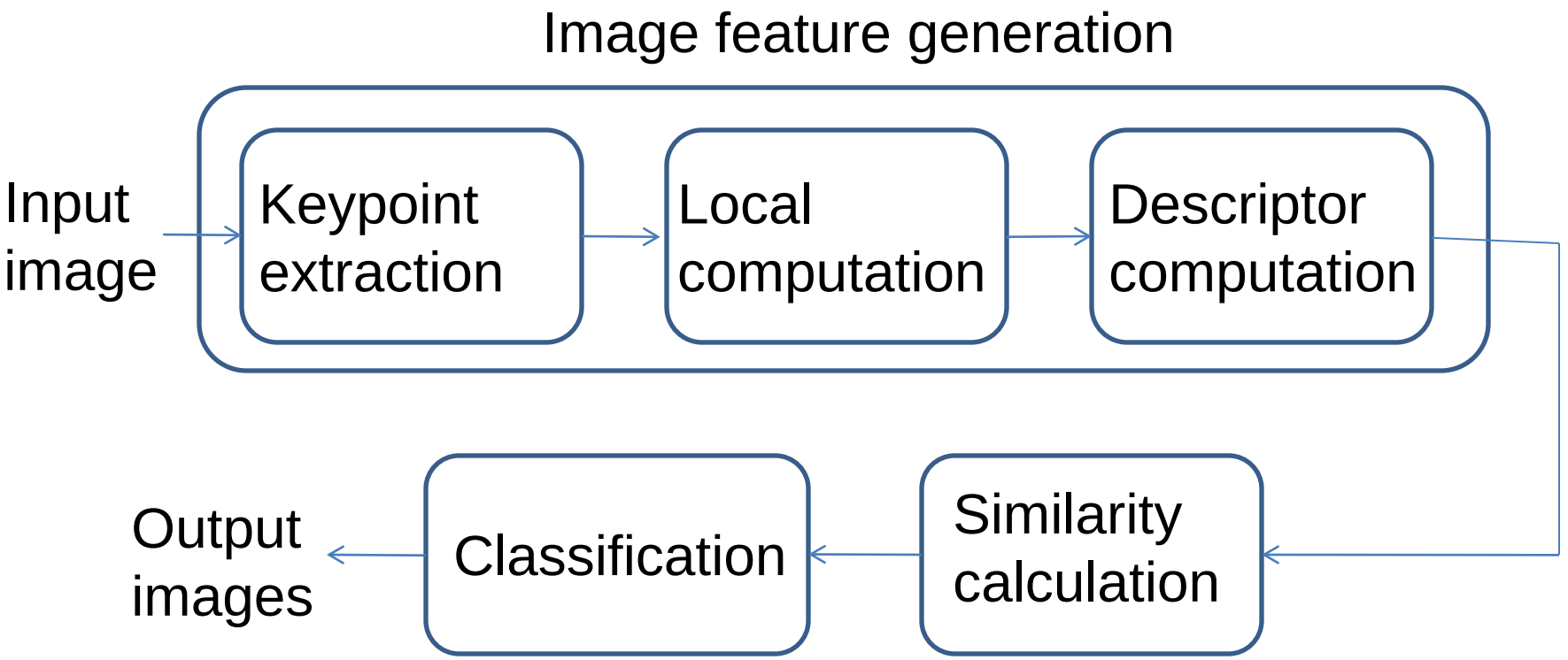
# No single partitioning fits all due to heterogeneity

- Diverse environments
  - » Device platform
  - » Network
  - » Cloud
- Diverse workloads

Dynamic Partitioning

Dynamically shifting computation between weak device and cloud

# Example application for dynamic partitioning: image matching




SIFT (IJCV 2004), SURF (ECCV 2006)

# Workload

- Size of the image
- Content of the image
- Database size

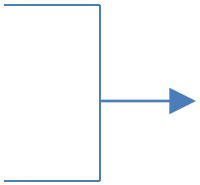


Image feature generation

Nearest neighbor search

# Device platform

- CPU: 500MHz w/o FPU <-> 2GHz w FPU
- Memory: 192MB <-> 2GB
- Persistent store: 256MB <-> 160GB
- Special units: GPU
- Charging mode
- More processing power, more memory
  -> More processing at the client

# Network

- 3G, WiFi
- Wimax, LTE
- Connection variation
- Faster networks -> send raw data and offload more processing to the server

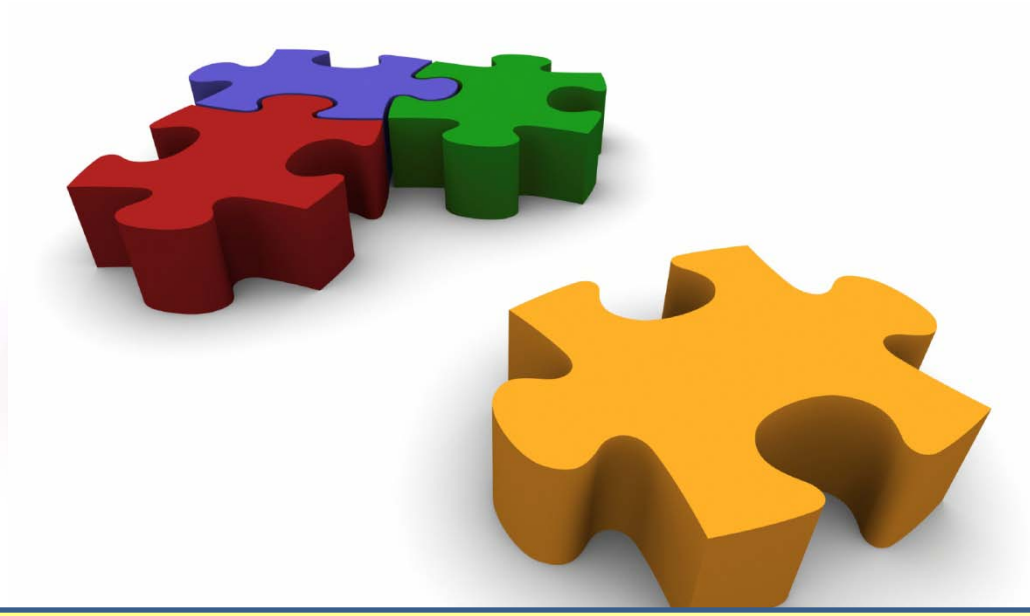
# Cloud

- Availability
- Distance
- Cost

# Problem formulation

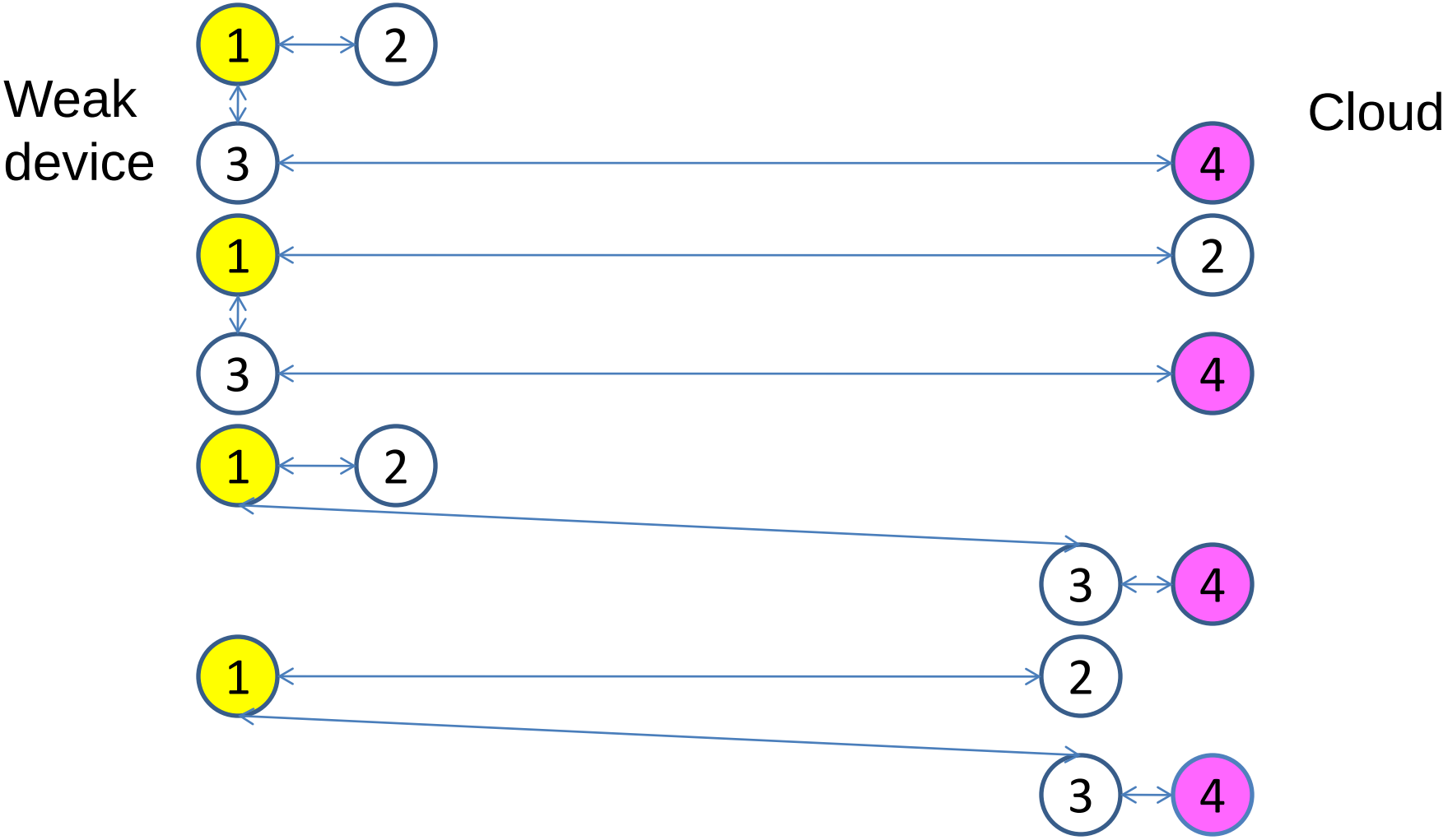
- Application: a set of modules interacting each other

# Problem formulation

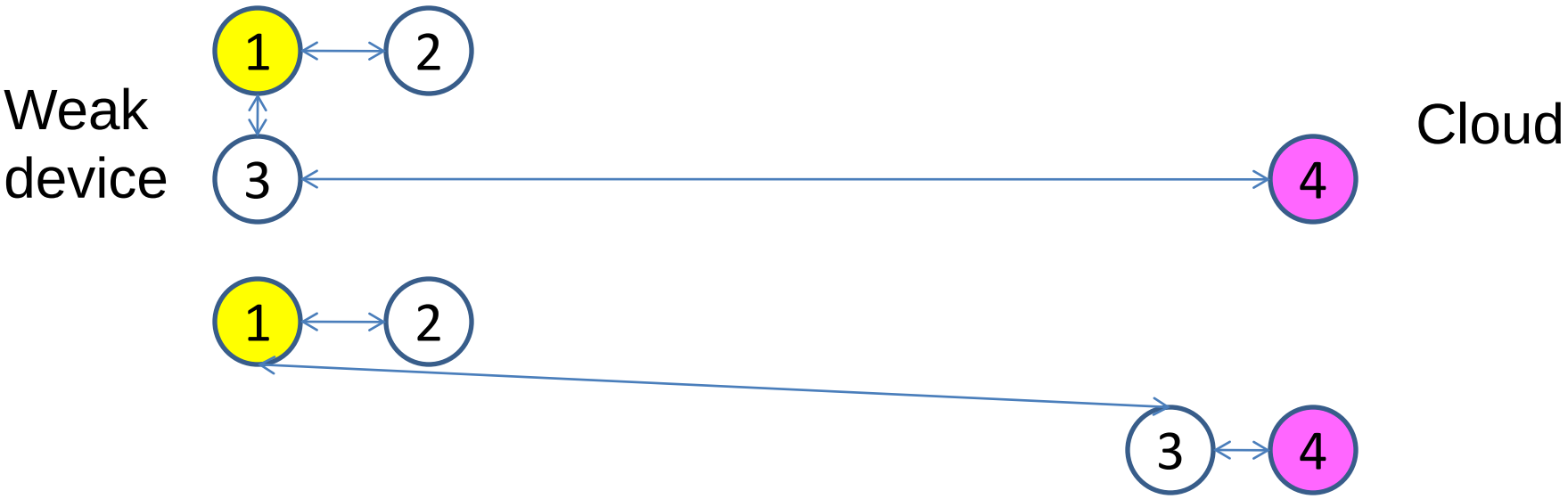


- Partitioning: multiple sets of modules that cover all application modules

# Partitioning example

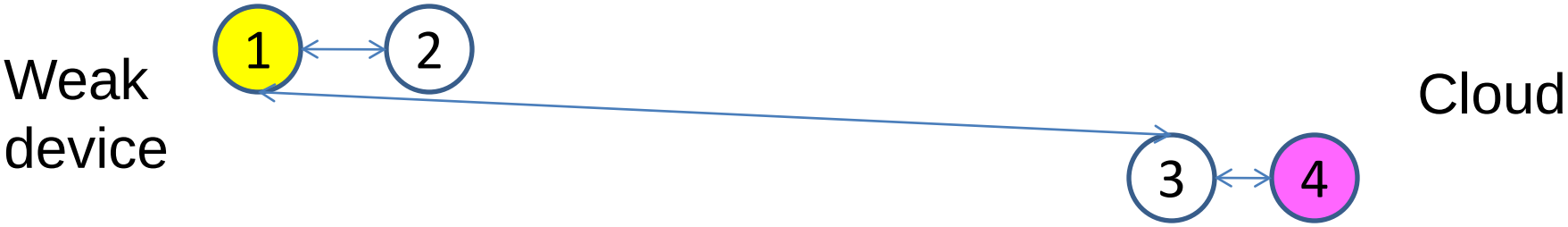


# Partitioning example




(E.g., 1 and 2 should be co-located)

# Partitioning example




(E.g., optimize energy consumption)

# Optimization

- Correctness
- Metric optimization

# Optimization

- Minimize $\sum_{i \in I} C(i)$ where

$$C(i) = \sum_{m \in Pd} C_p(m, d, i) + \sum_{m \in Ps} C_p(m, s, i) + \sum_{m1 \in Pd, m2 \in Ps} C_c(m1, m2, t, i)$$

subject to

$$m = P_d, \forall m \in L_1(d)$$

$$m = P_s, \forall m \in L_1(s)$$

$$m1, m2 \in P_d \quad or \quad m1, m2 \in P_s, \forall (m1, m2) \in L_2$$

# System support for dynamic partitioning

- Application structuring
- Partitioning choice
- Security of dynamic partitioning

# Application structuring

- Both client and server have all parts of the application
- Instantiate what modules to run at client and server dynamically at run time
- Wire them flexibly

# Partitioning choice

- Policy
  - » Goals: execution time, energy consumption, total money spent, security
- Mechanism
  - » Profile costs
  - » Online partitioning decision - prediction, fast optimization

# Security of dynamic partitioning

- A module containing sensitive data of a machine does not run at another machine
- Automated approaches of privacy preserving partitioning

# Case study: partitioning of mobile device applications

- Offload computation from mobile devices to servers : an example of C-S program partitioning
- Recent fine-grained partitioning proposals
  - » CloneCloud (HotOS 2009)
  - » MAUI (Mobisys 2010)

# Case study: CloneCloud v1

- Application structuring
  - » Create (trusted) clones
  - » Method-level partitioning
  - » Offload execution of partitioned methods
- Partitioning
  - » Profiling
  - » Program analysis
  - » ILP optimization

# Case study: CloneCloud v1

- Adaptation – prediction using ML
- Applications: image search, virus scanning, privacy-preserving targeted advertising

# Related work

- Static partitioning of C-S programs – Links, Hops, Hilda
- Programmer-assisted partitioning – Spectra, Chroma, Odyssey, Protium
- Automatic partitioning – Coign, Wishbone
- Class-level partitioning – AIDE, OLIE
- Partitioning via information flow types - Swift

# Summary

- Present dynamic partitioning between weak device and cloud in diverse environments and workloads
- Formalize the dynamic partitioning problem
- Discuss its system support

**Thank you!**
**Questions?**