CloneCloud

Augmented Smart Phone Applications Through Clone Cloud Execution

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Trend

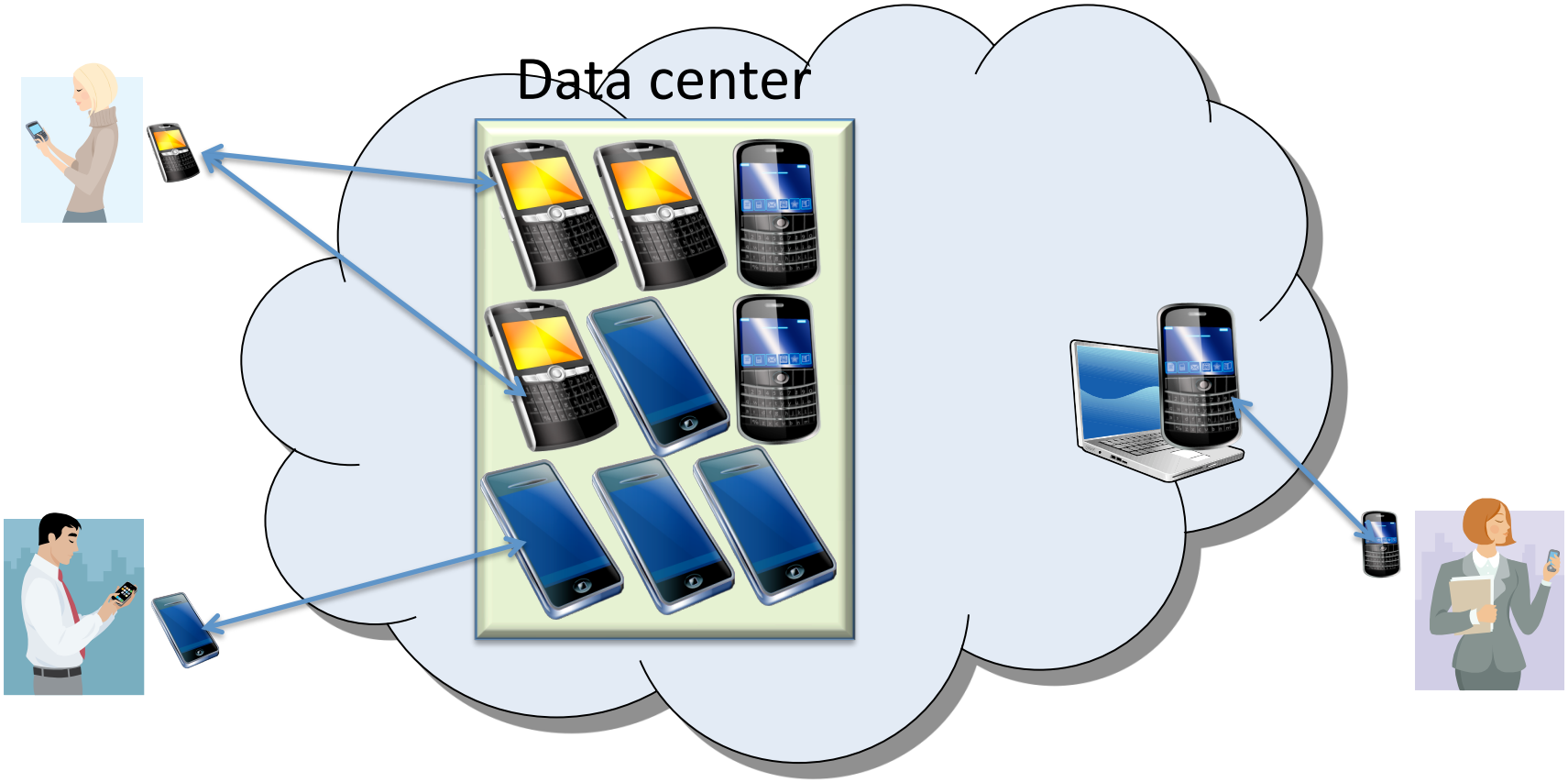
- Smart phones are recently seeing explosive adoption
  - Such devices see a wealth of new complex applications
- Users expect what they use in traditional desktop and server platforms
- But, still those applications are expensive to support when cast to mobile architectures

Capitalize on this opportunity

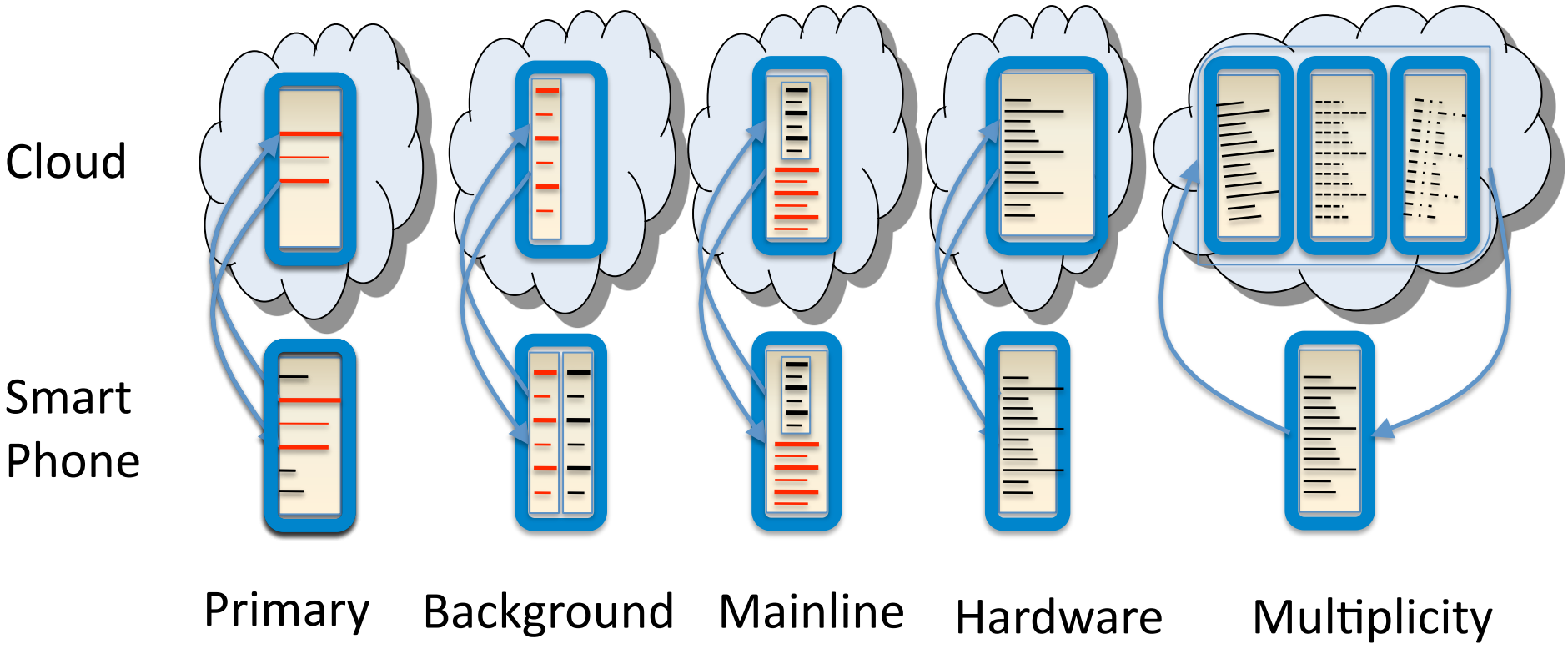
- We (re)discover an opportunity
  - Abundant, ubiquitous, and continuously reachable "cloud" (data center servers, desktops, laptops)
  - Fast, ubiquitous wireless connections
  - Replicating/migrating execution through virtualization technologies
- We propose a simple idea: let the smart phone host its expensive, exotic applications by augmenting its execution seamlessly

CloneCloud

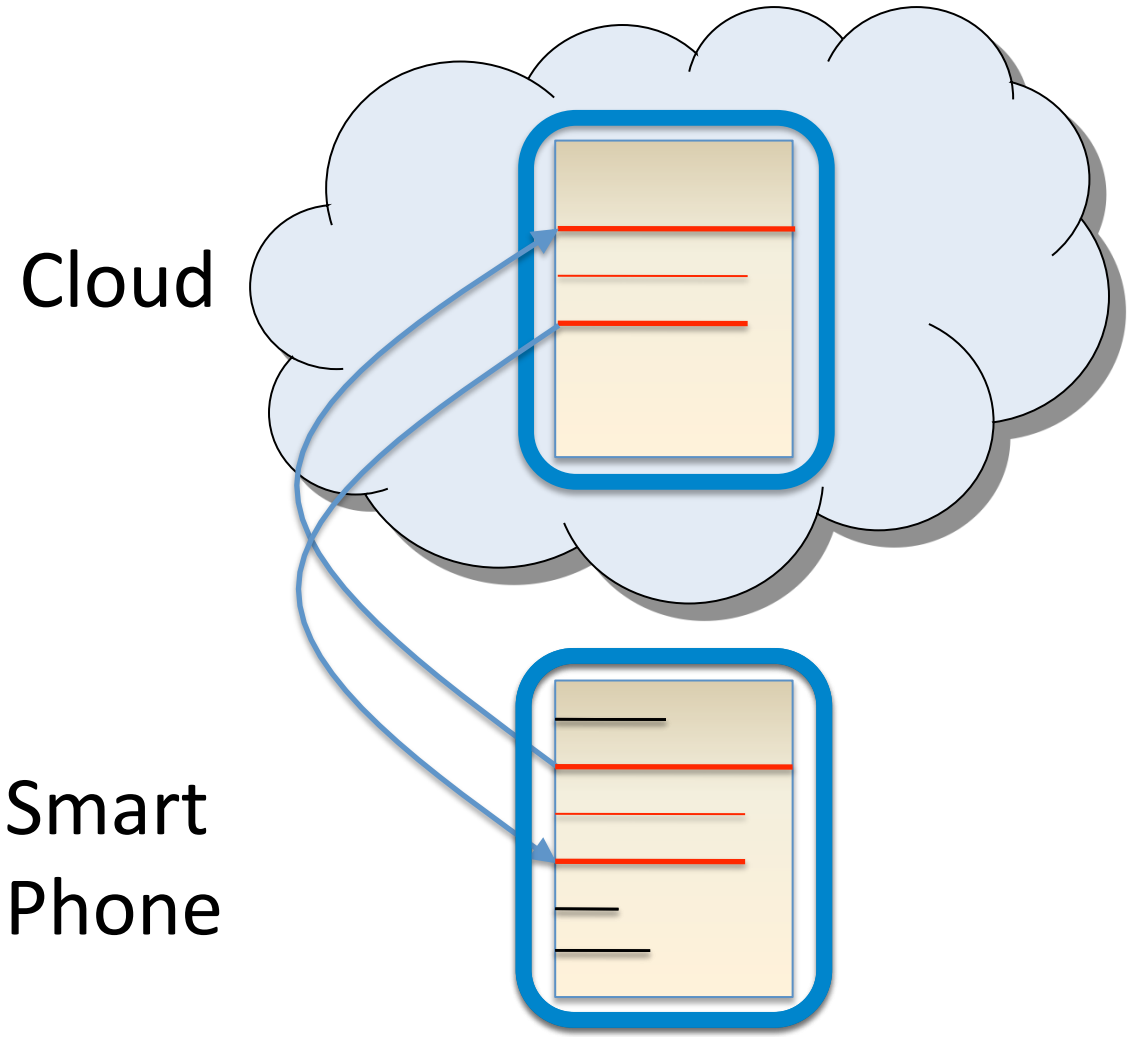
- Bring the power of cloud computing to your smart phones seamlessly.



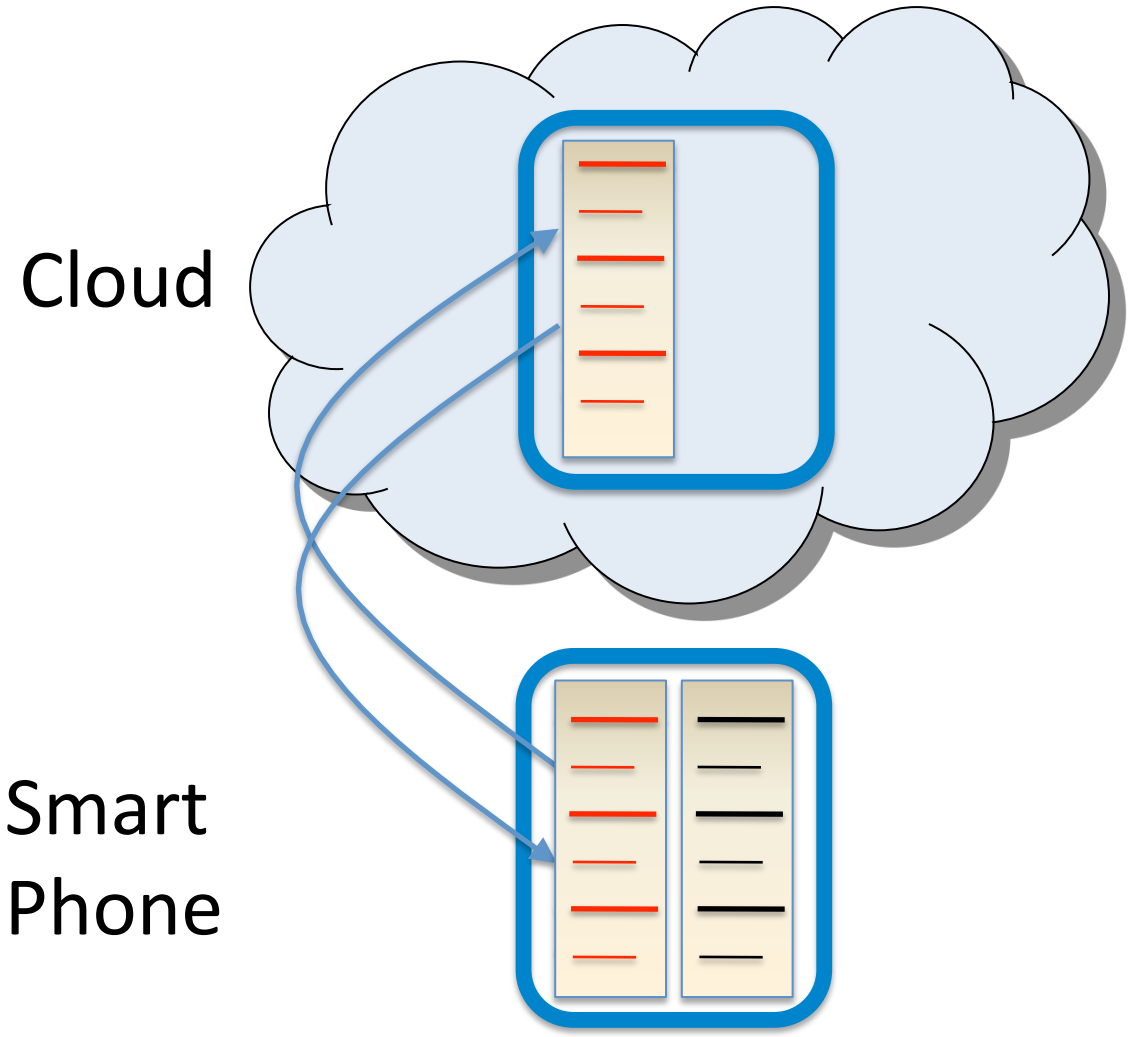
Augmented execution



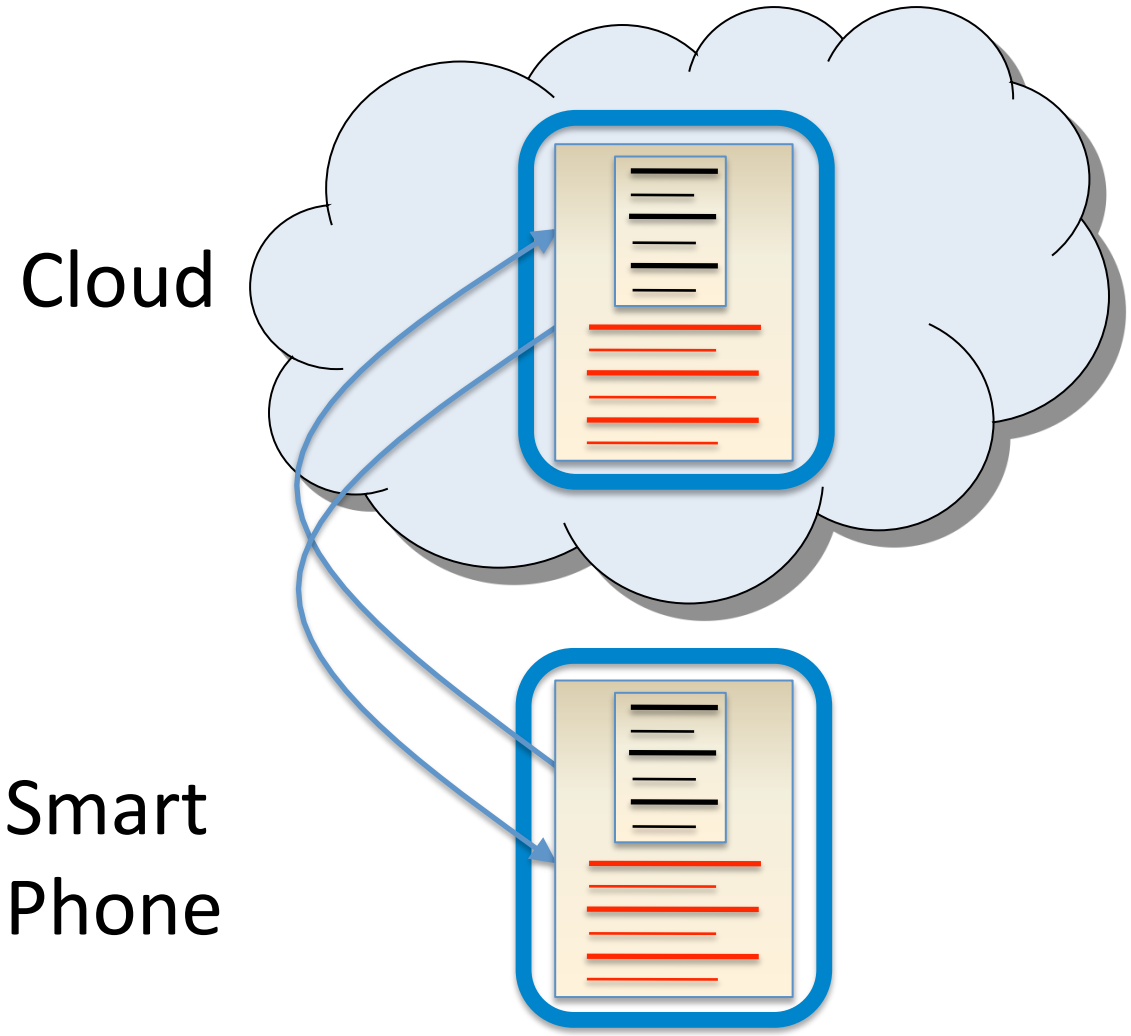
Primary functionality outsourcing



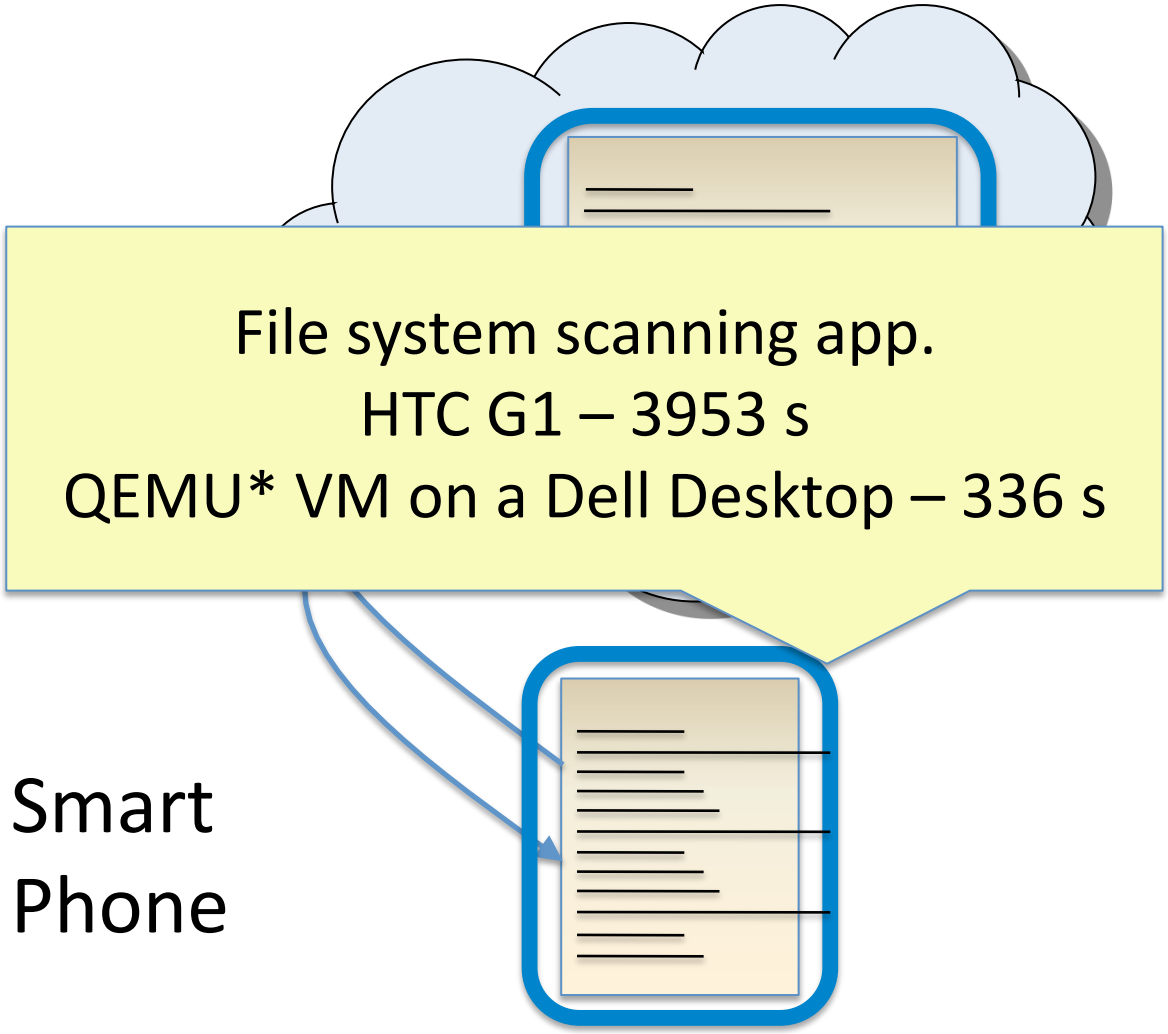
Background augmentation



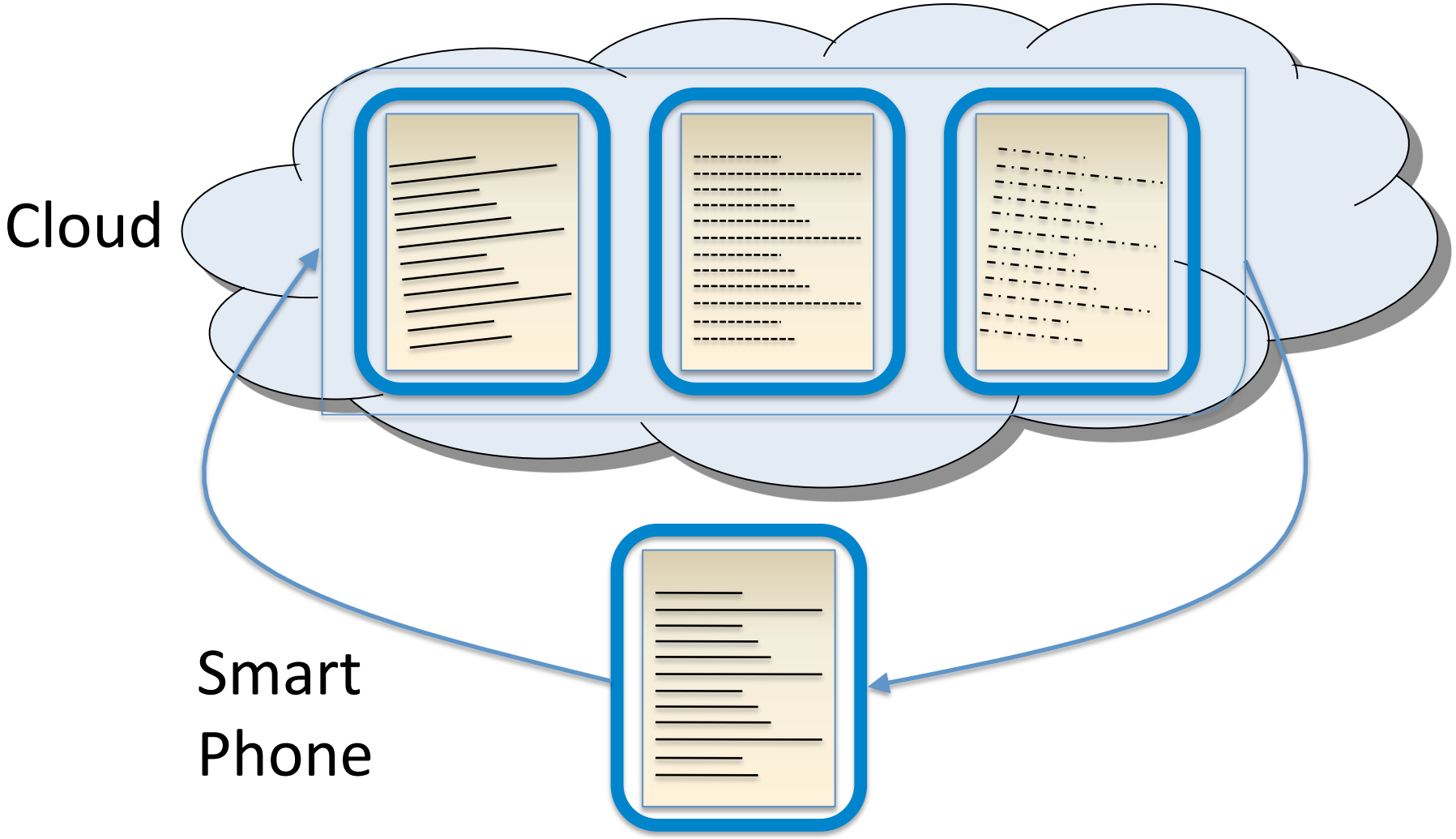
Mainline augmentation



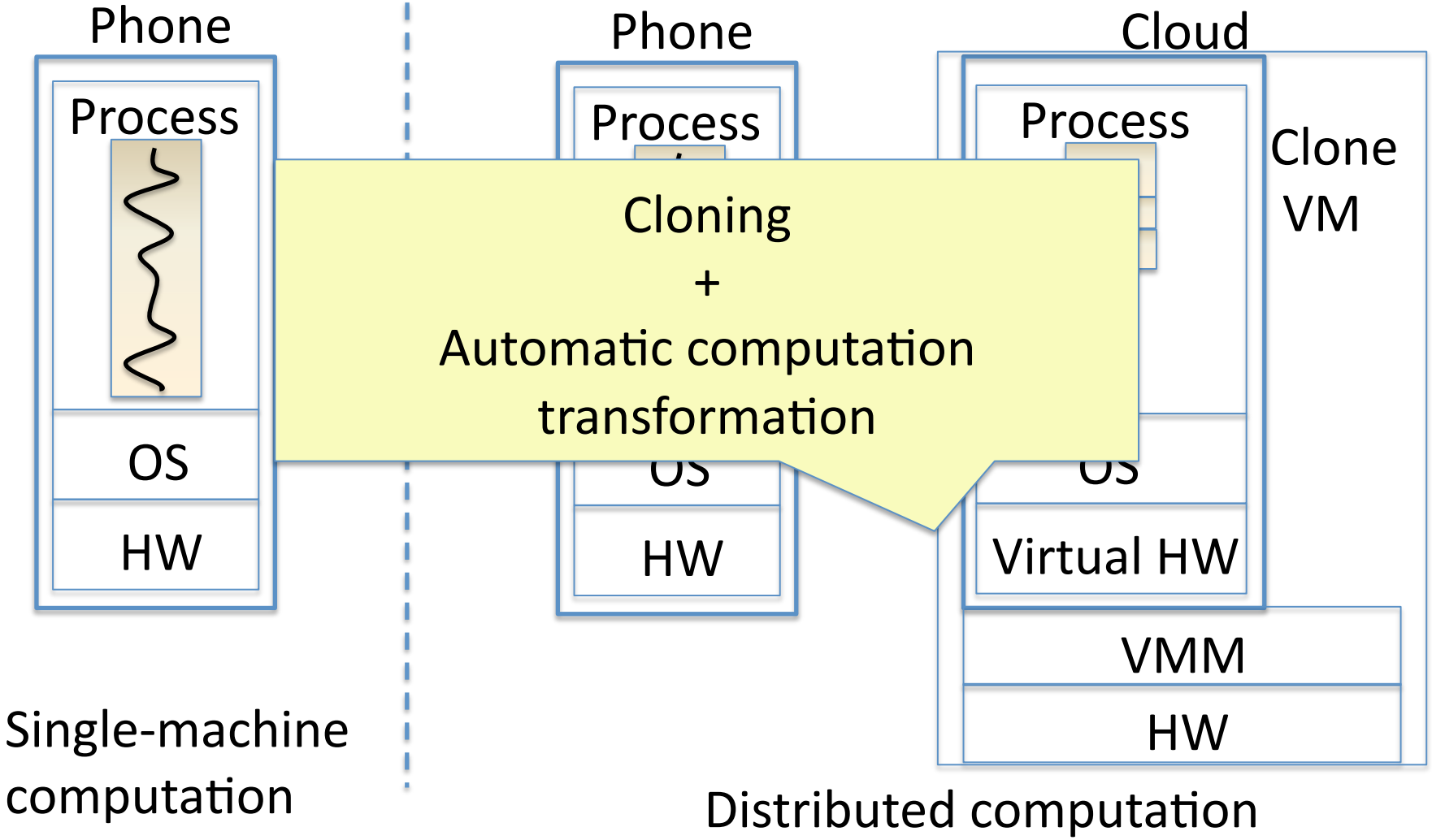
Hardware augmentation



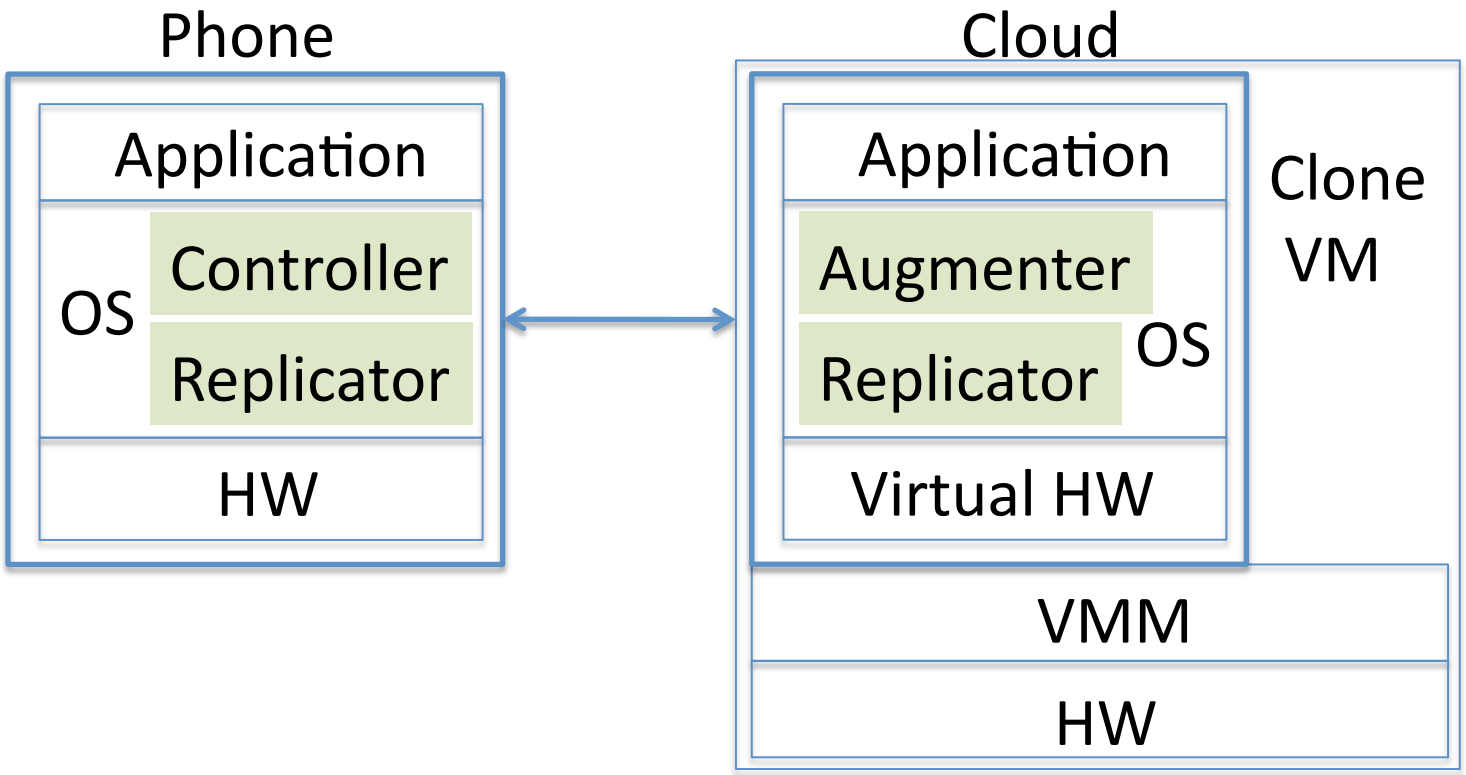
Augmentation through multiplicity



High-level system model



Clone execution architecture



Automation

- Developers write applications once for their smartphone platforms
- CloneCloud morphs applications automatically considering heterogeneity
  - Clones software of the smartphone
  - Synchronizes image incrementally and offloads execution in clone
  - Merges results back retroactively or not

Research agenda

- Computation transformation
- Coordination
- Boosting
- Trust
- Beyond smart phones

Computation transformation

- When to transform?
  - Applicability is application dependent
- Which part to transform?
  - Augmentation type
  - Run-time profiling and partitioning
  - Consider computation and network latency and resource usage such as power
- What to migrate?
  - Dalvik VM, Process container, VM

Coordination

- How to do synchronization efficiently?
  - Mechanism: incremental checkpointing, two-level synchronization
  - When and how to synchronize considering the tradeoffs between latency and resource usage
- How to coordinate execution?
  - Asynchronous notification, synchronous notification, speculative execution

Boosting

- How to do hardware augmentation?
  - Capability inflation: CPU clock rate, the number of virtual CPU cores, memory size, persistent store size of VMs
  - Feature exposure

Trust

- What if we cannot trust clone VM environments?
  - Public kiosks, digital signs
  - Taking the direction of trusted primitives (A2M (SOSP'07), MAS (FAST'09), TrInc (NSDI'09))
    - Certify computation done in clone VM using trusted hardware
    - Verify it using a simple proof

Beyond smartphones

- Hybrid data centers
  - Power-efficient, high-performance data centers using heterogeneous processors
- Heterogeneous cores

Related work

- Remote execution of resource-intensive applications for resource-poor hardware
  - Carefully designs and partitions applications between local and remote execution
    - Fox96, Rudenko98, Flinn99, Flinn01, Young01, Balan02
- ISR
- Cyber foraging – data staging, slingshot
- Coign
- DCC

Conclusion and current status

- Propose a new architecture that enables new, exciting augmented execution for smart phones with the power of cloud computing
- Are exploring synchronization, coordination, partitioning mechanisms and polices with Android platform

Thank you!
Questions?