Microsoft

EXTREME COMPUTING GROUP

Defining the future.

Cloud Programming

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New Programming Model, New Problems (and some old, unsolved ones)

Concurrency

Parallelism

Message passing

Distribution

High availability

Performance

Application partitioning

Defect detection

High-level abstractions

Concurrency

Inherently concurrent programming

- Asynchronous, message-driven model
- Multiple requests streams

Threads or events??

- Threads offer familiar sequential programming model
  - But, state can change when thread is preempted (synchronization)
  - Cost of thread and context switch limits concurrency
- Handlers fracture program control flow
  - Logic split across event handlers
  - Explicit manipulation of local state (no stack frames)

Higher-level (state machine, Actor, …) models?

Lack of consensus inhibits research, development, reuse, interoperability

- Parallel programming, redux

Parallelism

Computers are parallel
- Increased performance + power efficiency

Computers will be heterogeneous
- Multiple, non-isomorphic functional units

Data centers are vast message-passing clusters
- Availability and throughput

Parallel programming is long-standing sore point for computer science
- State of the art: threads and synchronization (assembly language)
- No consensus on shared memory semantics

New research on higher-level models is not panaceas
- Transactional memory
- Deterministic parallelism

Radical proposal: abolish shared memory
- Message passing is inherent in distributed systems, so why 2 models?
- Shared memory is difficult and error prone

Message Passing

Fundamental in distributed systems and better programming model

- Performance / correctness isolation
- Well-defined points of interaction
- Scalable

More difficult to use

- Little language support
  - Erlang integrates message with pattern matching
  - Sing# channel contracts
  - Sing# postbox semantics
- Message passing libraries
  - Fundamental mismatch: asynchronous strange in a synchronous world

Open problems

- Control structures for asynchronous messages
- Communications contracts
- Integration of messages in type system and memory model

Distribution

Distributed systems are rich source of difficult problems

- Replication
- Consistency
- Quorum

Well-studied field with good solutions

- Outsider's perspective: research has focused on fundamental problems and techniques used in real systems

Common abstractions

- Replication
- Relaxed consistency
- Persistence

How can these techniques be incorporated into programming model?

- Libraries
- Language integration
- New models

Availability


Democrat and Chronicle

BLACKOUT

Services must be highly available

- Blackberry/Google/… outage gets national media attention
- Affect millions of people simultaneously
- Service becomes part of national infrastructure

High availability is challenge

- Starts with design and engineering
- Hard to eliminate all "single points of failure"
- Murphy's law rules
- Antithetical to rapid software evolution

Programming models provide little support for systematic error handling

- Disproportionate software defects in error-handling code
  - Afterthought
  - Run in inconsistent state
  - Difficult to test
- Erlang has systematic philosophy of fail and notify (but stateless)
- Could lightweight transactions simplify rollback for stateful languages?

Performance

Performance is system-level concern
- Goes far beyond the code running on a machine
- Most performance tools focus on low-level details

Current approach is wasteful and uncertain
- Build, observe, tweak, overprovision, pray

Performance should be specified as part of behavior
- SLAs as well as pre-/post-conditions

Need scalability
- Grow by adding machines, not rewriting software

Architecture should be the starting point
- Model and simulate before building a system
- What is equivalent of Big-O notation for scalability?

Adaptivity
- Systems need to be introspective and capable of adapting behavior to load
- e.g., simplify home page when load spikes, defer low-priority tasks, provision more machines, …

Power


Fig. 600. Kolben & Co.

New challenge is power consumption

- Processor performance limited by power
  - Multicore only a temporary solution – "dark silicon"
- Data center locally and globally power constrained
  - Significant cost (CAPEX + OPEX)

Power-efficient software design and construction

- Equivalent of asymptotic analysis for power?
- How to measure power consumption?
- How to compare alternatives?
- Design patterns

Application Partitioning

Static partition of functionality between client and server

- Clients have different architectures and capabilities
- Adapt to changing constraints (e.g., battery)
- Move computation to data, particularly when communications constrained
- Code mobility
  - Exists in data center (VMs), why not across data center boundary?

Currently, client and server are two fundamentally different applications

- Evolution around interfaces
- Volta (Microsoft)
  - Single program model, compiled for server and client

Defect Detection

Considerable progress in past decade on defect detection tools

- Tools focused on local properties (e.g., buffer overruns, test coverage, races, etc.)
- Little work on system-wide properties

Modular checking

- Whole program analysis expensive and difficult
- Not practical for services
- Assertions and annotations at module boundaries
- Can check global properties locally
- e.g., Rajamani & Rehof's Conformance Checking

New domain of defects

- Message passing
- Code robustness
- Potential performance bottlenecks

High-Level Abstractions

Map-reduce and dataflow abstractions simplify large-scale data analysis in data centers

- Convenient way to express problems
- Hide complex details (distribution, failure, restart)
- Allow optimization (speculation)
- Not appropriate for services

Need abstractions for wider range of problems

- Interactive applications

Orleans

Goals

- Simple, widely accessible programming model
- Encourage use of scalable, resilient software architectures
- Raise level of abstraction (CLR – Windows ≈ Orleans – Azure)

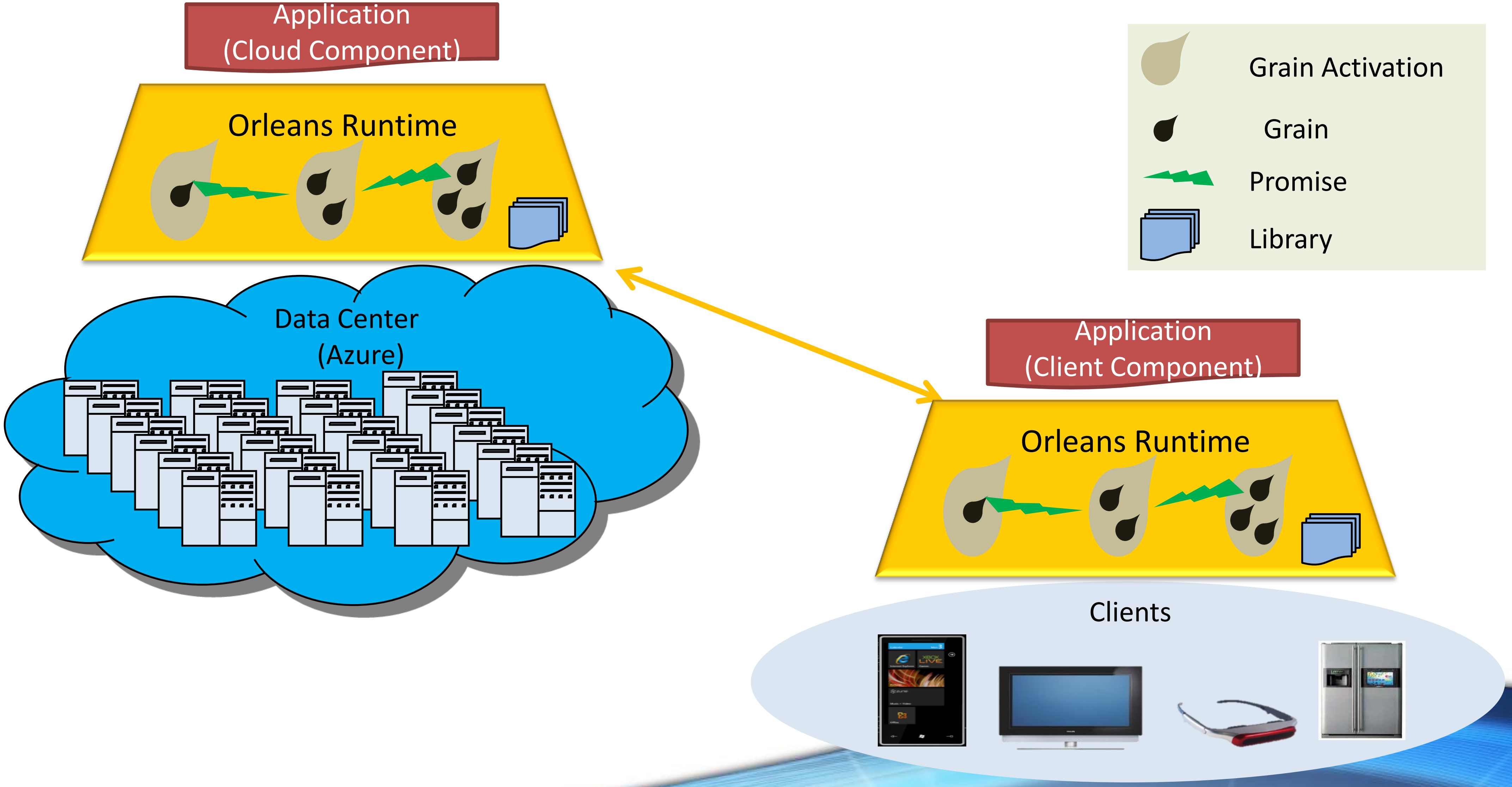
Grains are unit of computation and data storage (Actors)

- Can migrate between data centers
- Replication, consistency, persistence handled by runtime system

One programming model for client and server

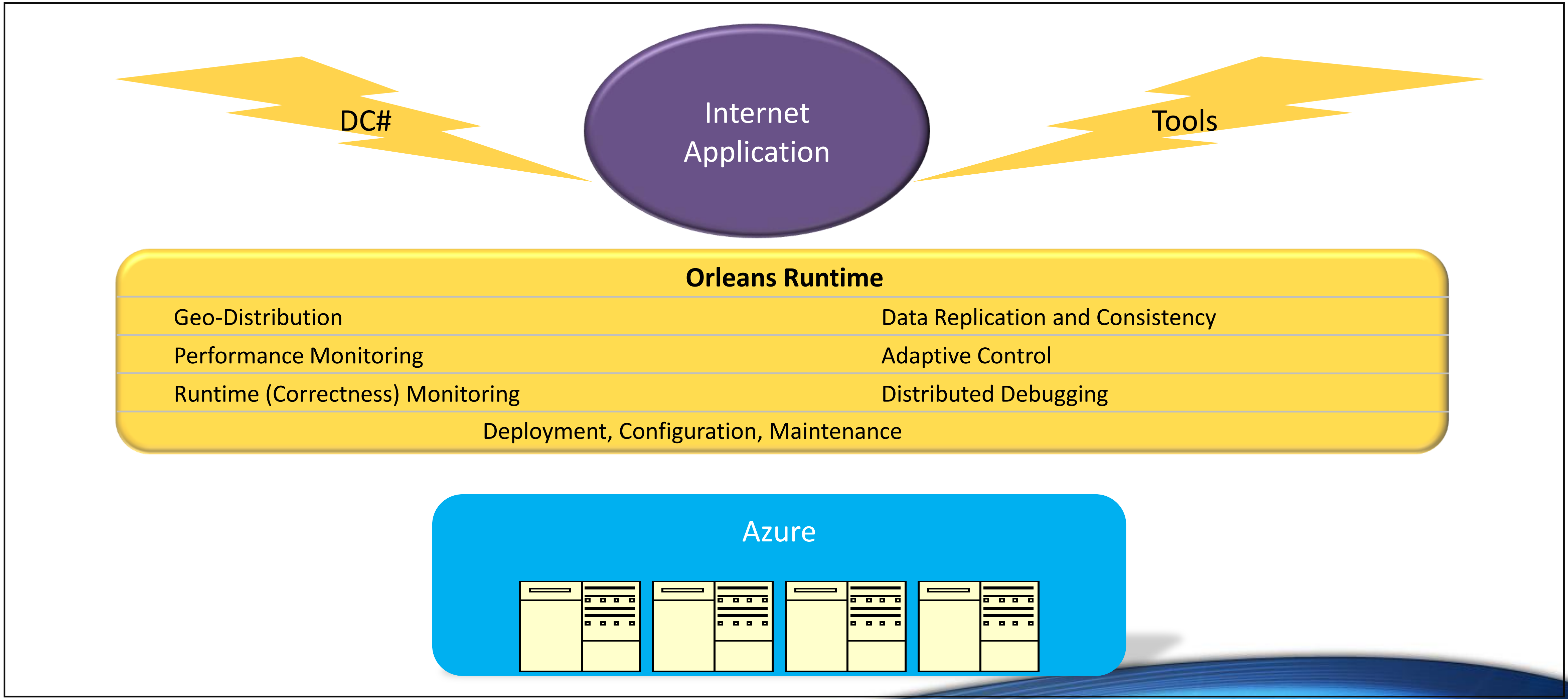
- Simplify development, debugging, performance tuning, etc.
- Single-source distributed programs (eg Volta)
- Enable code mobility

Orleans



Application
(Cloud Component)
Orleans Runtime
Data Center
(Azure)
Grain Activation
Grain
Promise
Library
Application
(Client Component)
Orleans Runtime
Clients

Orleans Architecture



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