MegaPipe : A New Programming Interface for Scalable Network I / O

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OSDI, 2012

Presented By Dong Yuan, 2015210938

Background

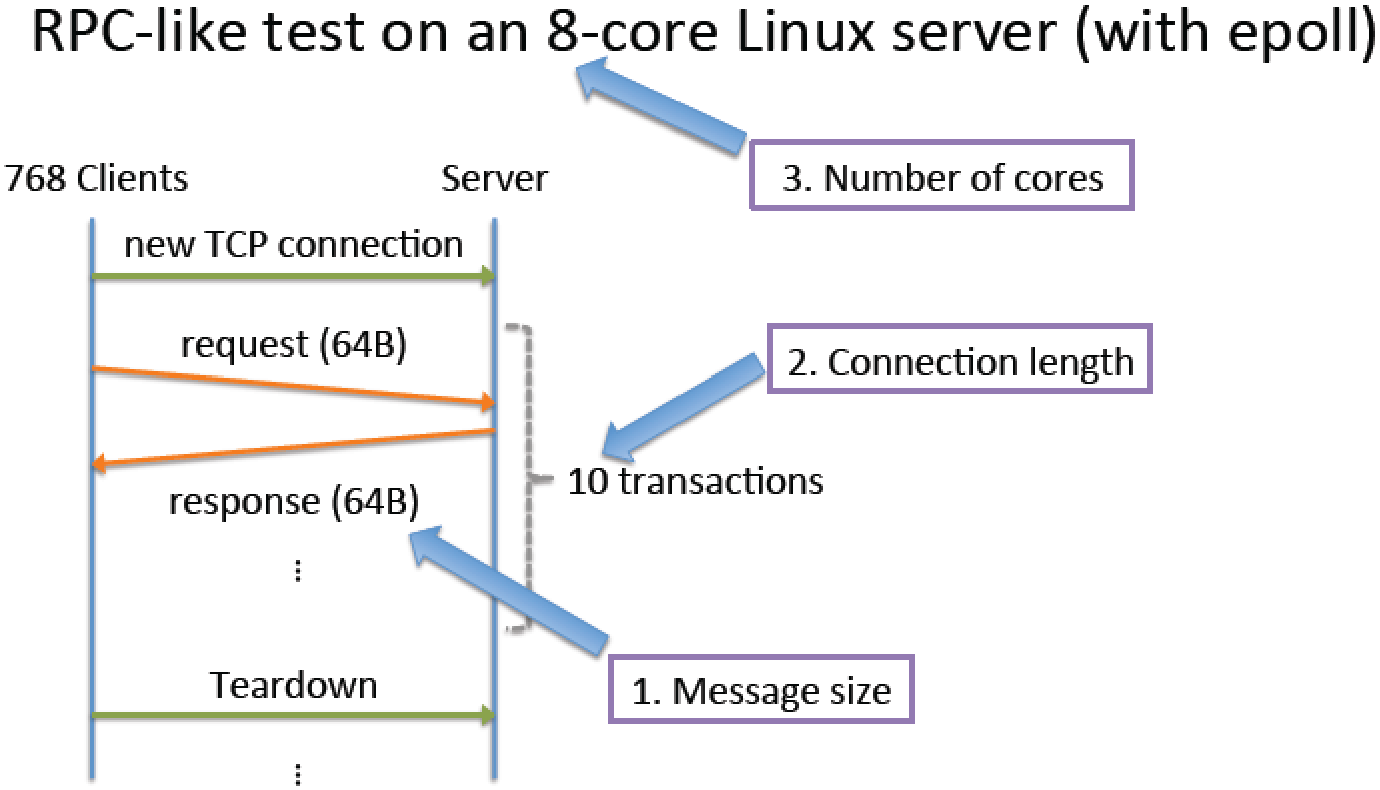
- Message-Oriented Workload
  - Short connections or small messages
    - Examples: HTTP, RPC, DB

- Issues with message-oriented workloads
  - System call overhead
  - Shared listening socket
  - File abstraction overhead

Solved Issues Comparison with mTCP & Fastsocket

- MegaPipe (OSDI, 2012)
  - System call overhead
  - Shared listening socket
  - File abstraction overhead
- mTCP (NSDI, 2014)
  - Shared resources
  - Broken locality
  - Per packet processing
- Fastsocket (ASPLOS, 2016)
  - Shared resources
  - Broken locality
  - Uncompatible API

Microbenchmark



RPC-like test on an 8-core Linux server (with epoll)

3. Number of cores

768 Clients

Server

new TCP connection

request (64B)

response (64B)

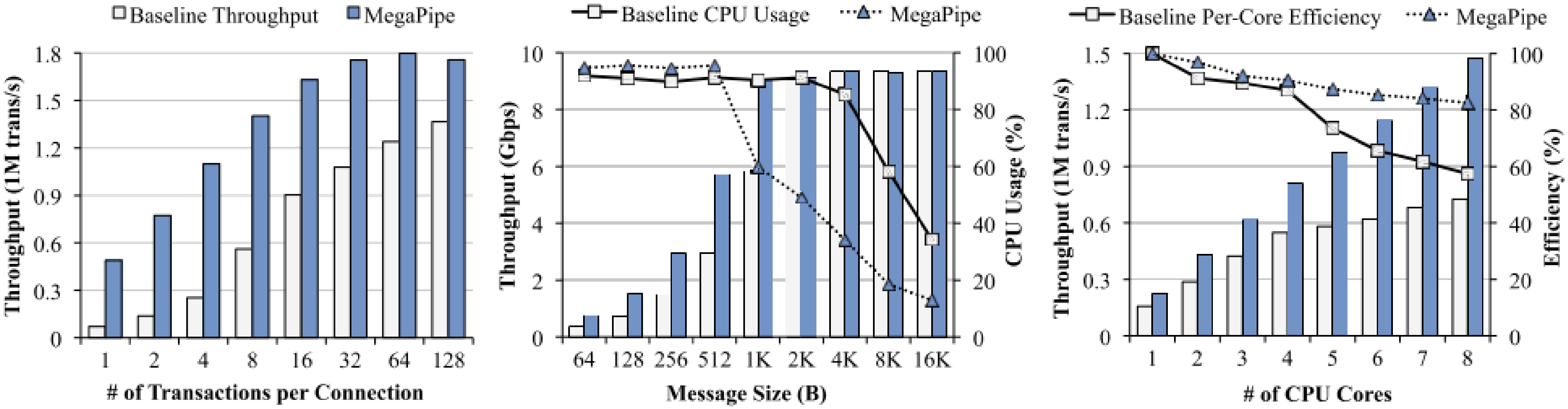
10 transactions

2. Connection length

1. Message size

Teardown

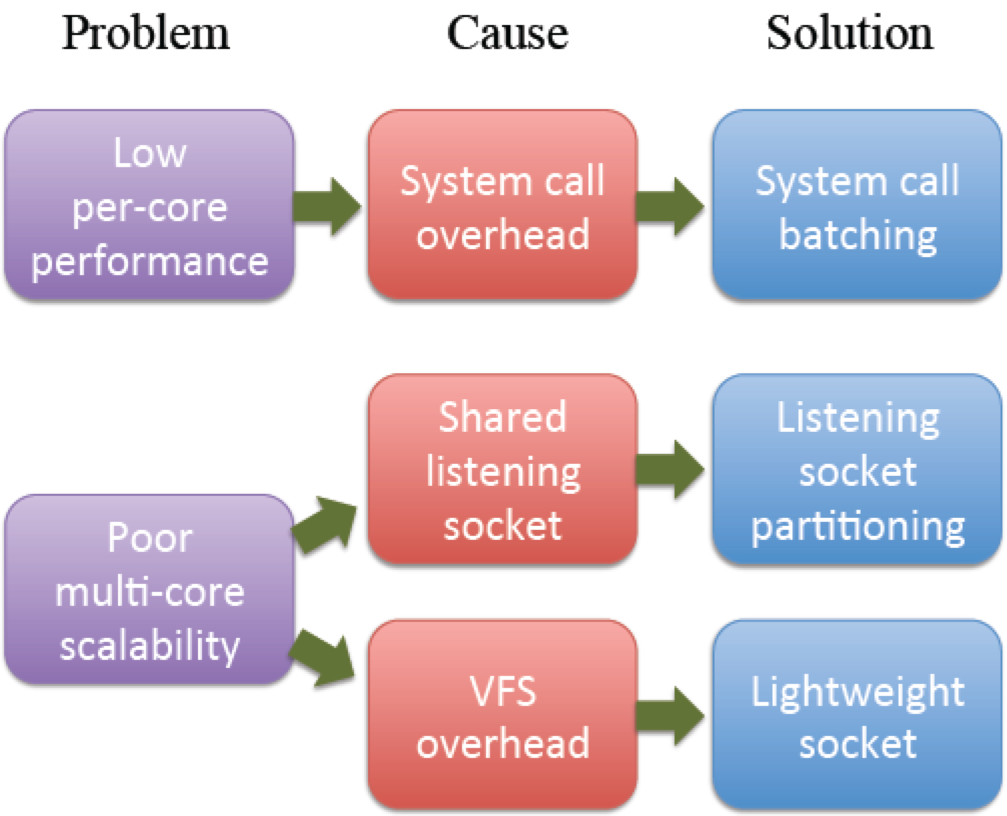
Performance of Message-Oriented Workloads



Design Goal

- API, applicable to existing event-driven server applications with moderate efforts
- Unified interface for various I/O types, TCP connection, UNIX domain sockets, disk files…
- Low overhead & multi-core scalability

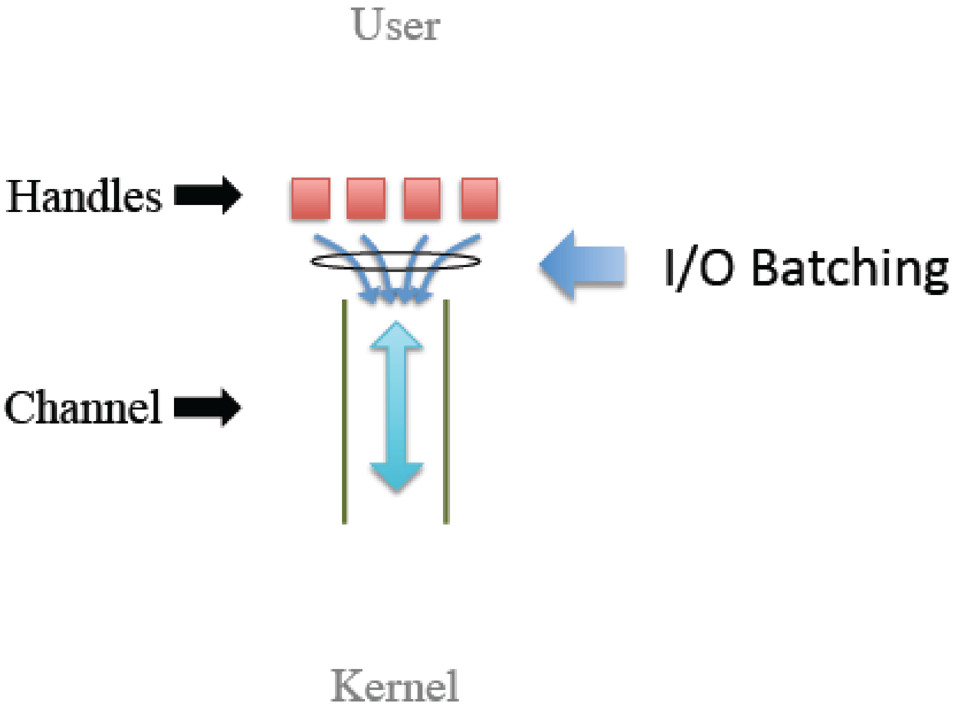
Overview


Problem
Cause
Solution
Low per-core performance
System call overhead
System call batching
Poor multi-core scalability
Shared listening socket
Listening socket partitioning
VFS overhead
Lightweight socket

Key Primitives

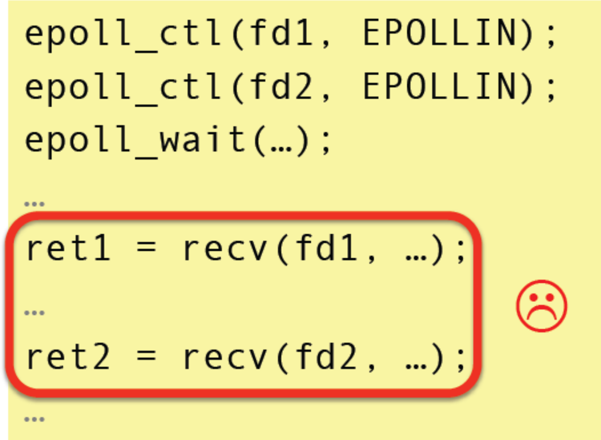
- ***Handle***
  - Similar to file descriptor
    - But only valid with in a channel
  - TCP connection, pipe, disk file…

- ***Channel***
  - A per-core, bi-directional pipe between the kernel and user
  - Multiplexes I/O operations of its handles



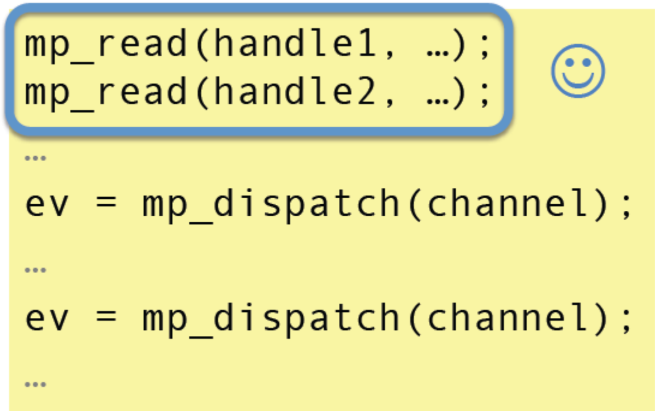
Completion Notification Model

- Application issue asynchronous I/O commands
- Kernel notifies the application when the commands are complete
- Why CNM?
  - CNM allows transparent batching of I/O commands and notifications
  - It is compatible with not only sockets but also disk files
  - Simplify the complexity of I/O multiplexing



```
epoll_ctl(fd1, EPOLLIN);
epoll_ctl(fd2, EPOLLIN);
epoll_wait(…);
…
ret1 = recv(fd1, …);
…
ret2 = recv(fd2, …);
…
```

Readiness Model

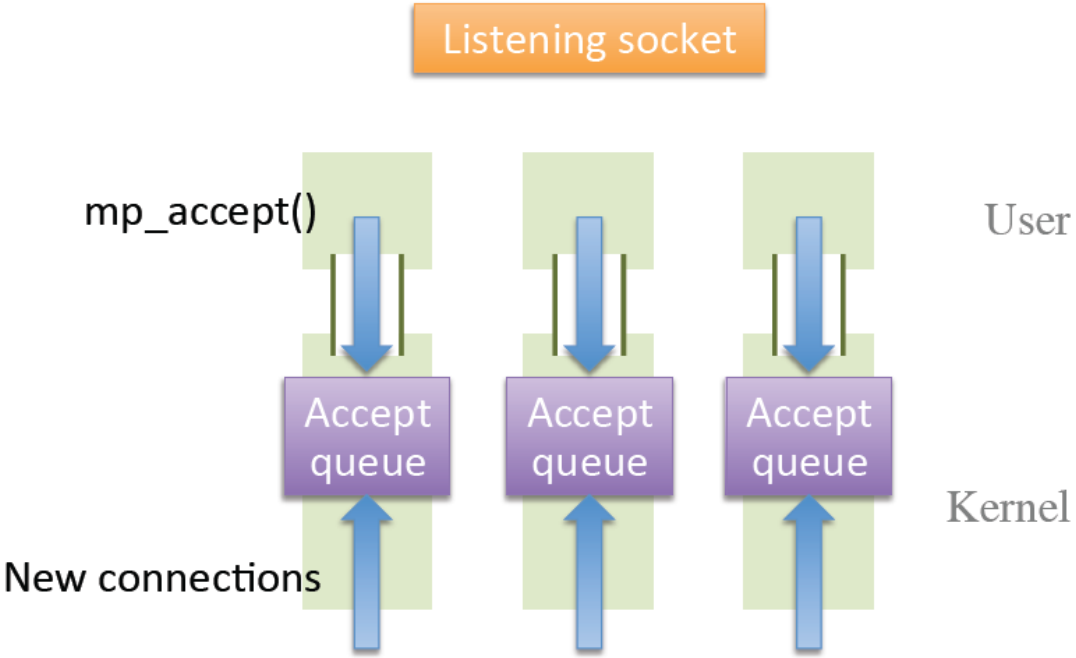


```
mp_read(handle1, …);
mp_read(handle2, …);
…
ev = mp_dispatch(channel);
…
ev = mp_dispatch(channel);
…
```

CNM

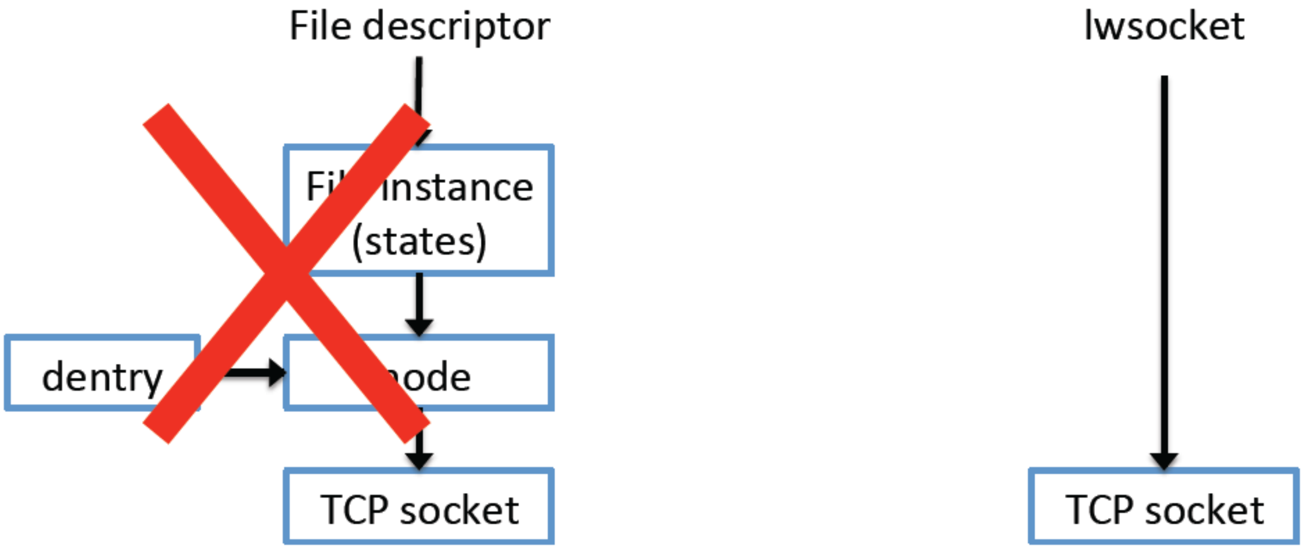
Listening Socket Partitioning

- Per-core accept queue for each channel
  - Instead of the globally shared accept queue



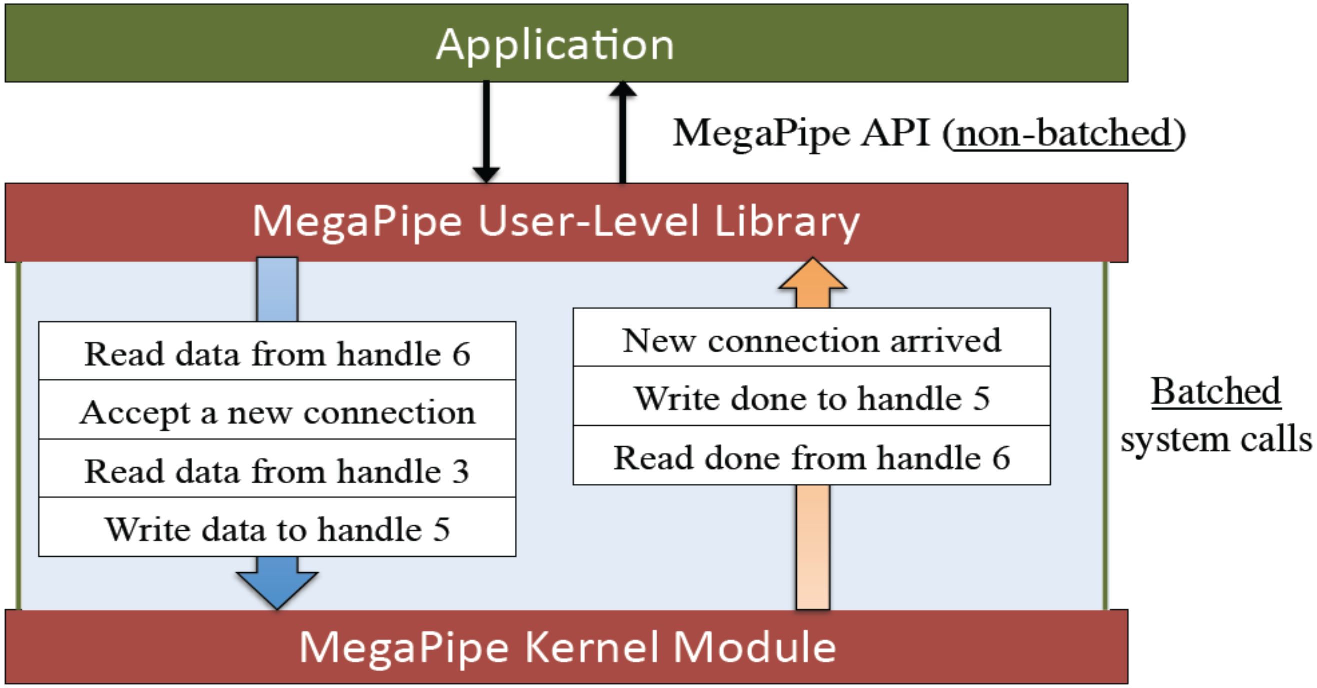
Lightweight Socket

- Sockets are ephemeral and rarely shared
  - Bypass the VFS layer
  - Convert into a regular file descriptor only when necessary



System Call Batching

- System calls are expensive due to cost of mode switching and bad cache locality
- Transparent batching

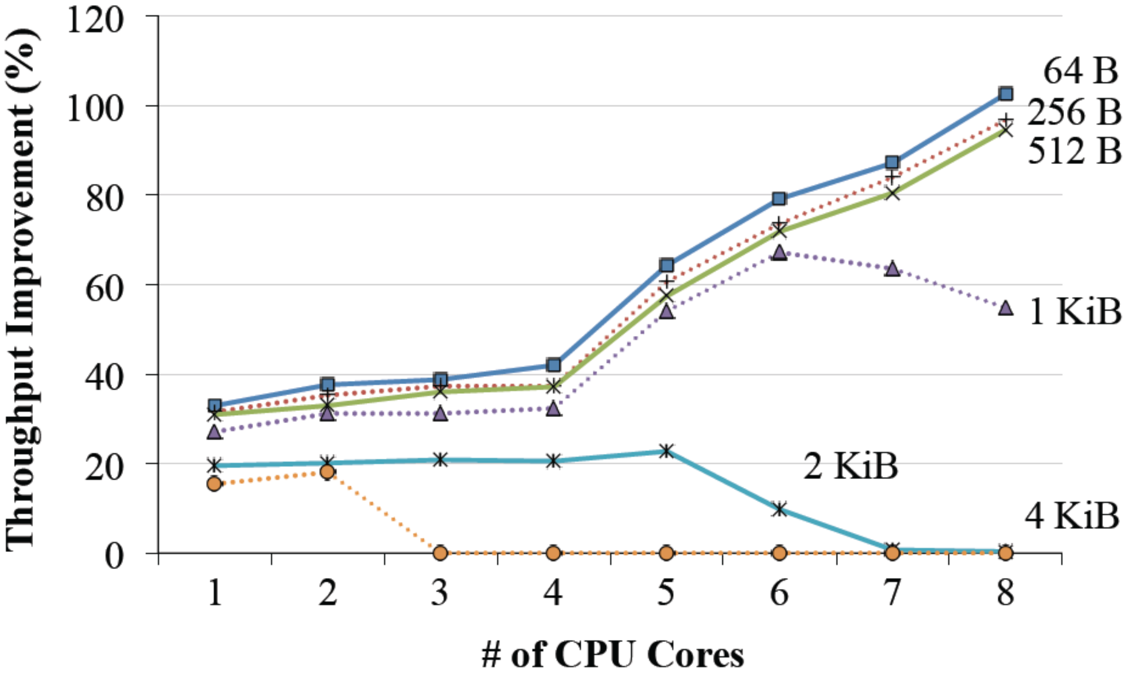


Implementation

- Kernel
  - One kernel module (~1800 lines)
  - Kernel itself (~400 lines)
- User-Level Library
  - ~400 lines
- Application
  - Supportive to event-driven server
  - ~hundreds of lines

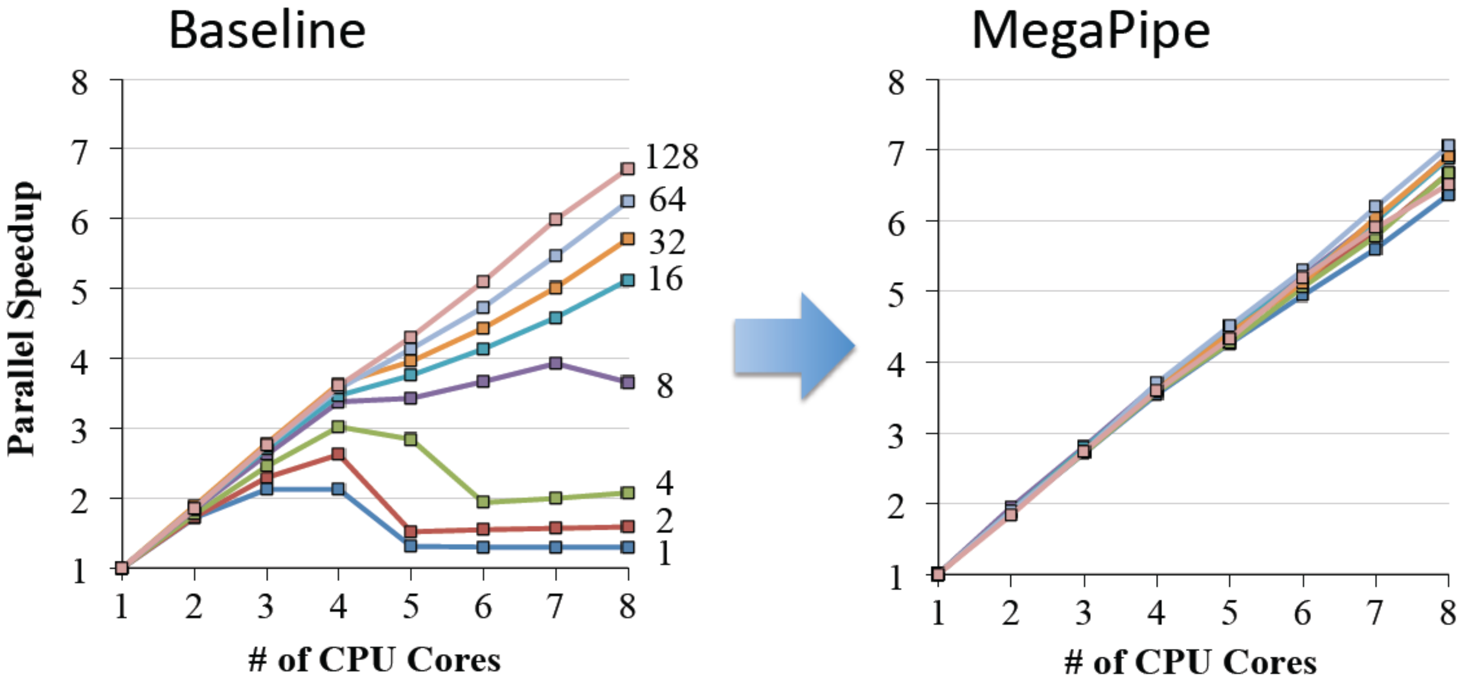
Evaluation

- Multi-core scalability
  - Throughput improvement with various message sizes



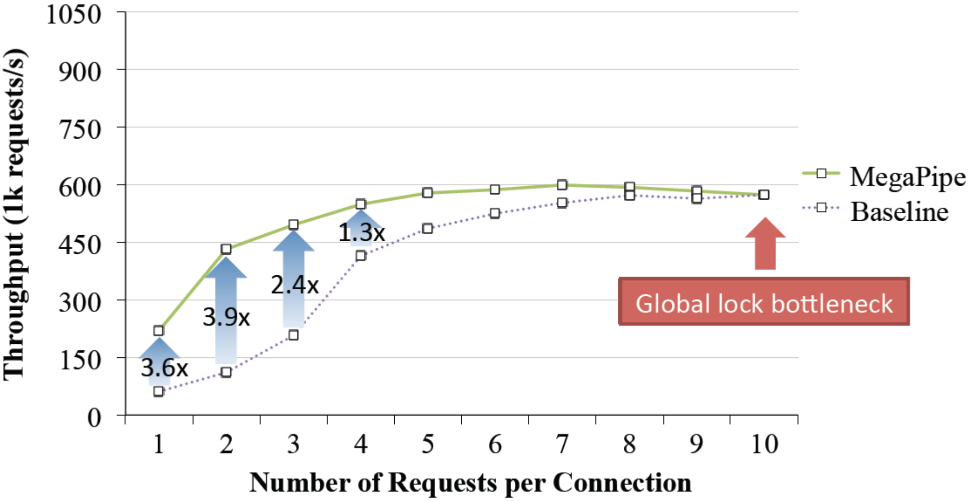
Evaluation

- Multi-core scalability
  - Throughput improvement with various connection lengths (# of transactions)

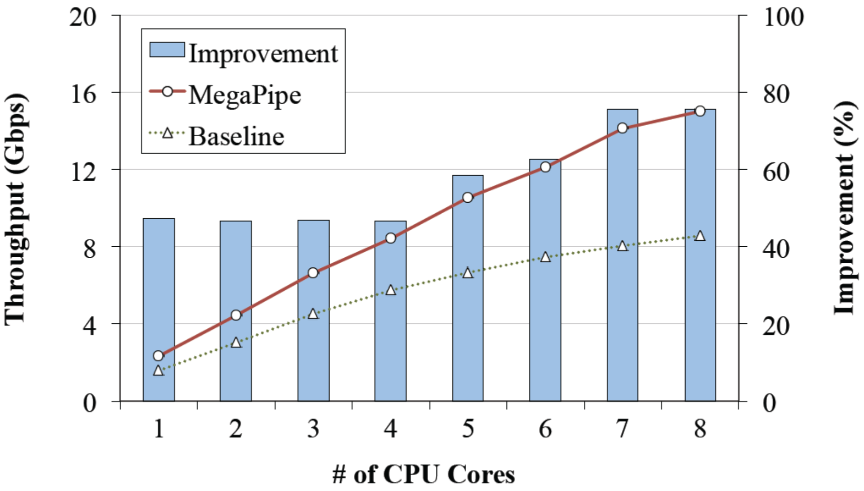


Application Evaluation

- Memcached



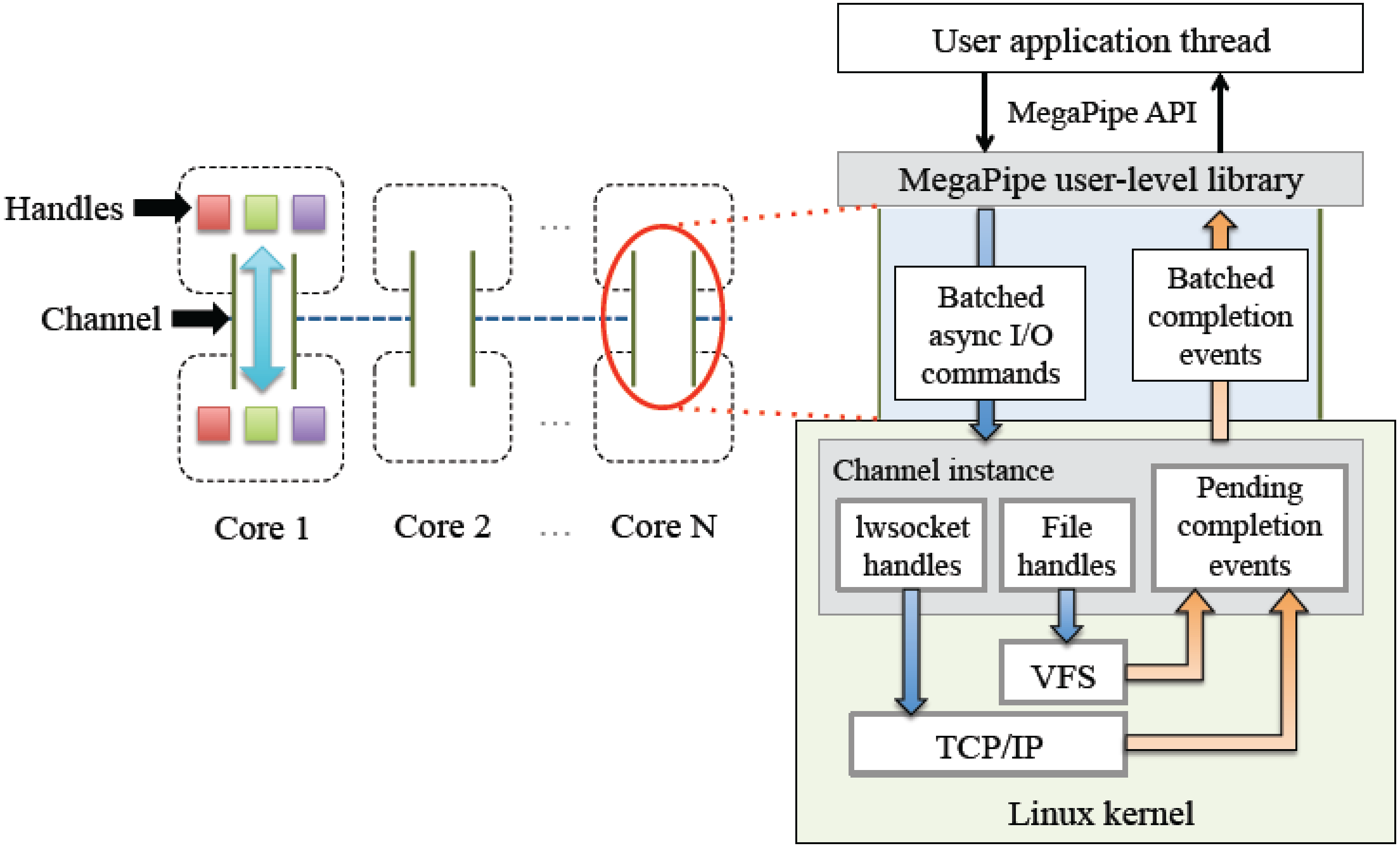
- nginx



Conclusion

- MegaPipe
  - Key abstraction: per-core channel
  - Enabling three optimization:
    - Batching, partitioning, lwsocket
  - Performance improvement in multi-core scalability and application

Comments About This Paper


User application thread
MegaPipe API
MegaPipe user-level library
Handles
Channel
Core 1
Core 2
...
Core N
Batched async I/O commands
Batched completion events
Channel instance
lwsocket handles
File handles
Pending completion events
VFS
TCP/IP
Linux kernel