Lecture 35: More on One Sided Communication

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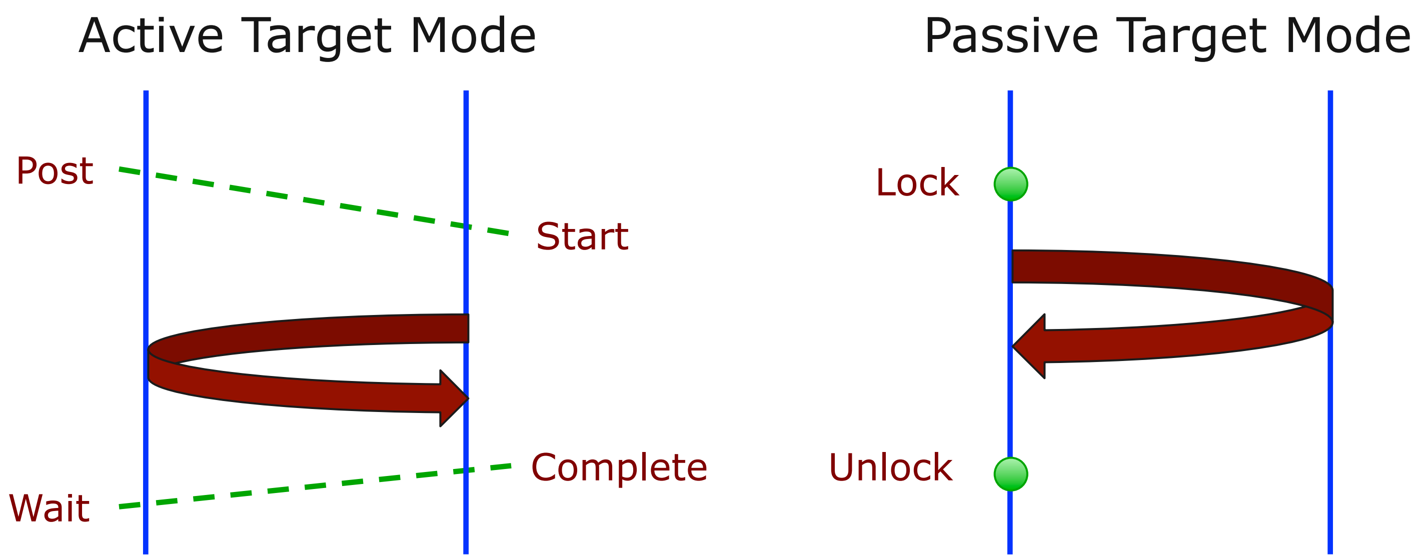
Synchronization in MPI RMA

- Active target requires cooperation by all processes in the group of the window object
  - MPI_Win_fence, MPI_Win_{post/start/complete/wait/test}
  - Good for many but not all RMA applications
- What if each process may need to independently access data?
  - Use Passive target synchronization

Lock/Unlock: Passive Target Synchronization



- Passive mode: One-sided, *asynchronous* communication
  - Target does **not** participate in communication operation
- Shared memory-like model

Passive Target Synchronization

```
MPI_Win_lock(int locktype, int rank, int assert, MPI_Win win)
```

```
MPI_Win_unlock(int rank, MPI_Win win)
```

```
MPI_Win_flush/flush_local(int rank, MPI_Win win)
```

- Lock/Unlock: Begin/end passive mode epoch
  - Target process does not make a corresponding MPI call
  - Can initiate multiple passive target epochs to different processes
  - Concurrent epochs to same process not allowed (affects threads)
- Lock type
  - SHARED: Other processes using shared can access concurrently
  - EXCLUSIVE: No other processes can access concurrently
- Flush: Remotely complete RMA operations to the target process
  - After completion, data can be read by target process or a different process
- Flush_local: Locally complete RMA operations to the target process

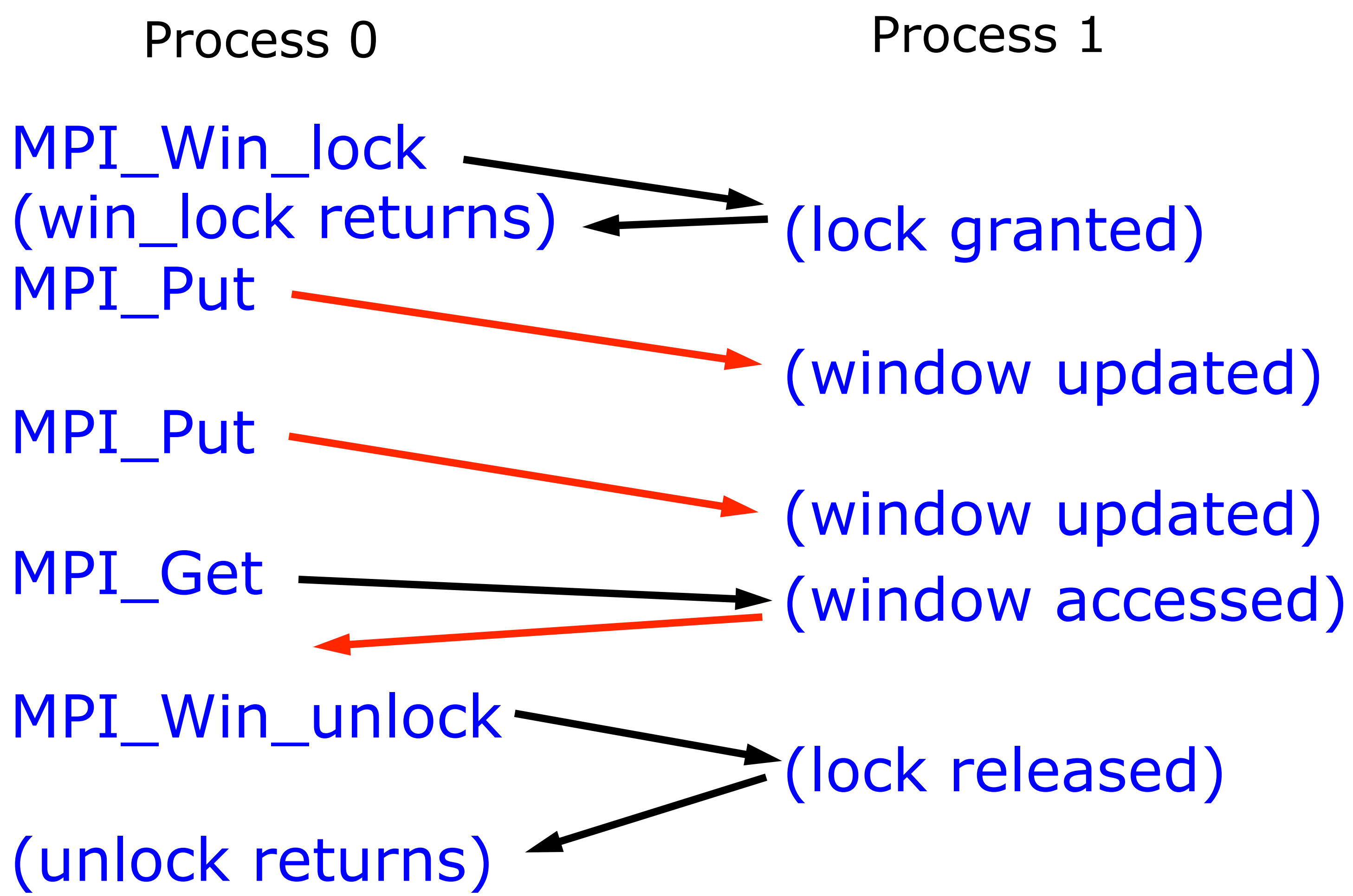
Lock is not Lock

- The name "Lock" is unfortunate
  - ♦ Lock is really "begin epoch"
  - ♦ Unlock is really "end epoch"
- An MPI "Lock" does not establish a critical section or mutual exclusion
  - ♦ With "MPI_LOCK_EXCLUSIVE" the RMA operations have exclusive access to the data they access/update during the time that they access the remote window
  - ♦ This is very different than a "lock" in the sense of a thread lock

Understanding the MPI RMA Completion Model

- Very relaxed
  - To give the implementer the greatest flexibility
  - Describing this relaxed model precisely is difficult
    - Only Implementer needs to obey the rules
  - But it doesn't matter; simple rules work for most programmers
- When does the data actually move?

Data Moves Early



Data Moves Late

Process 0		Process 1
MPI_Win_lock	(save information)	
MPI_Put	(save information)	
MPI_Put	(save information)	
MPI_Get	(save information)	
MPI_Win_unlock	→	(acquire lock, process requests, release lock)
(unlock returns)	←	

Understanding Why Late May Be Good

- Use a simple performance model:
  - Assume data size is small
  - Each communication on network takes time L
- Early approach:
  - 8 separate messages, so 8L
- Late approach:
  - 2 messages (including data), so 2L
- Late approach is 4 x faster than the early approach for small amounts of data

Understanding Why Early May Be Good

- Use a simple performance model:
  - Assume data size is large
  - Each data communication on network takes time L+rn, each control message takes time L
  - Assume communication can be overlapped with computation or other communication, but that latency (L) cannot be overlapped

Understanding Why Early May Be Good

- Early approach:
  - 5L + 3(L+rn); all but the 8L can be overlapped with computation
- Late approach:
  - 2 messages, so 2L + 3rn. Nothing may be overlapped
- Assuming full overlap, Early is 8L and Late is 2L+3rn, so Late can be arbitrarily slower than Early; equal when n = 2L/r

Advanced Passive Target Synchronization

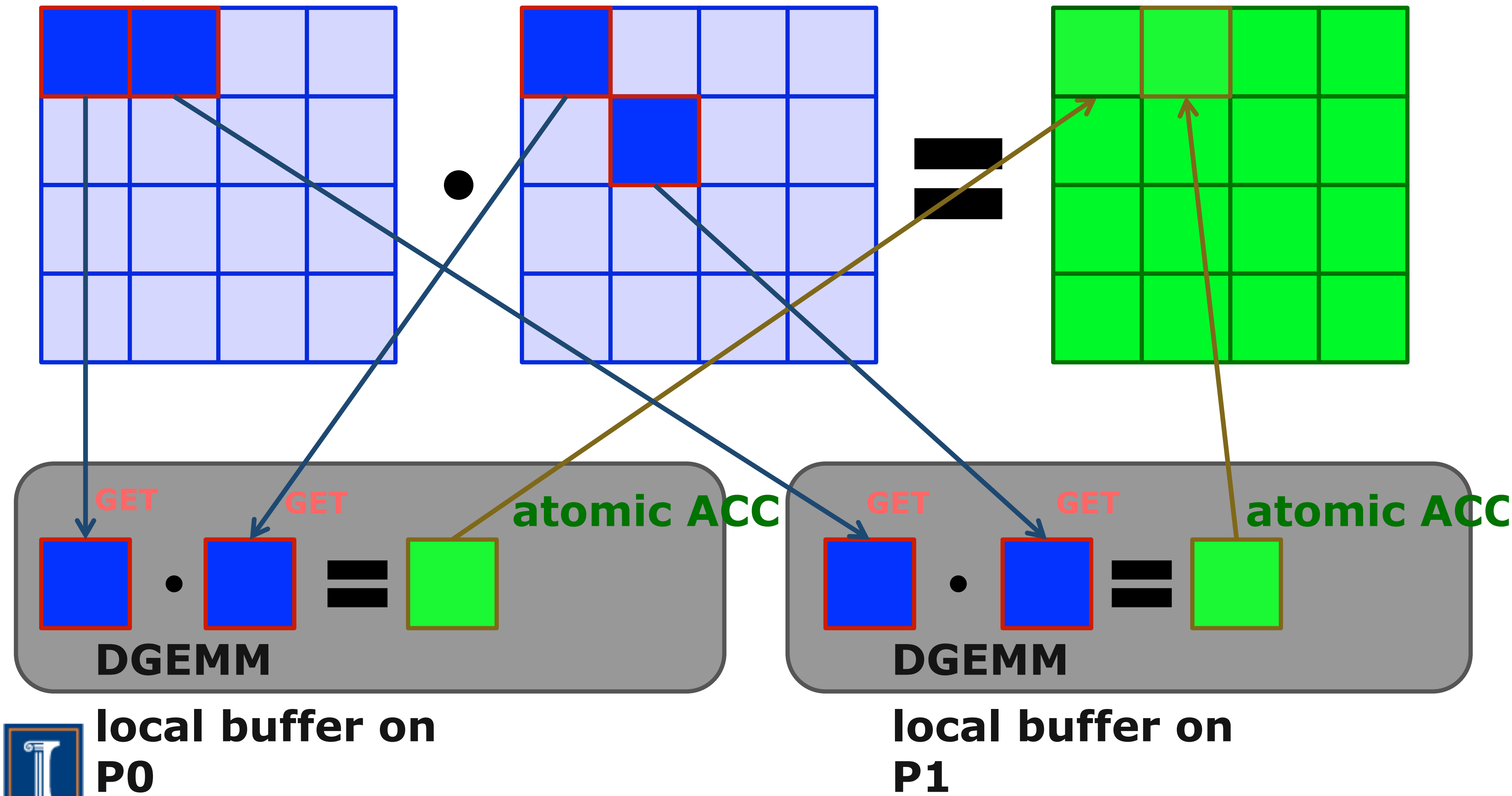
```
MPI_Win_lock_all(int assert, MPI_Win win)
```

```
MPI_Win_unlock_all(MPI_Win win)
```

```
MPI_Win_flush_all/flush_local_all(MPI_Win win)
```

- Lock_all: Shared lock, passive target epoch to all other processes
  - Expected usage is long-lived: lock_all, put/get, flush, …, unlock_all
- Flush_all – remotely complete RMA operations to all processes
- Flush_local_all – locally complete RMA operations to all processes

Implementing GA-like Computation by RMA Lock/Unlock



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Code Example

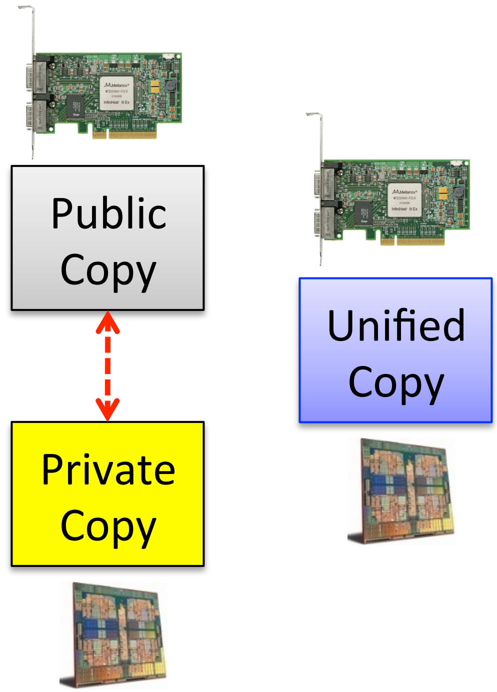
- ga_mpi_ddt_rma.c
- Only synchronization from origin processes, no synchronization from target processes
- Code thanks to Xin Zhao, posted on Moodle

Which synchronization mode should I use, when?

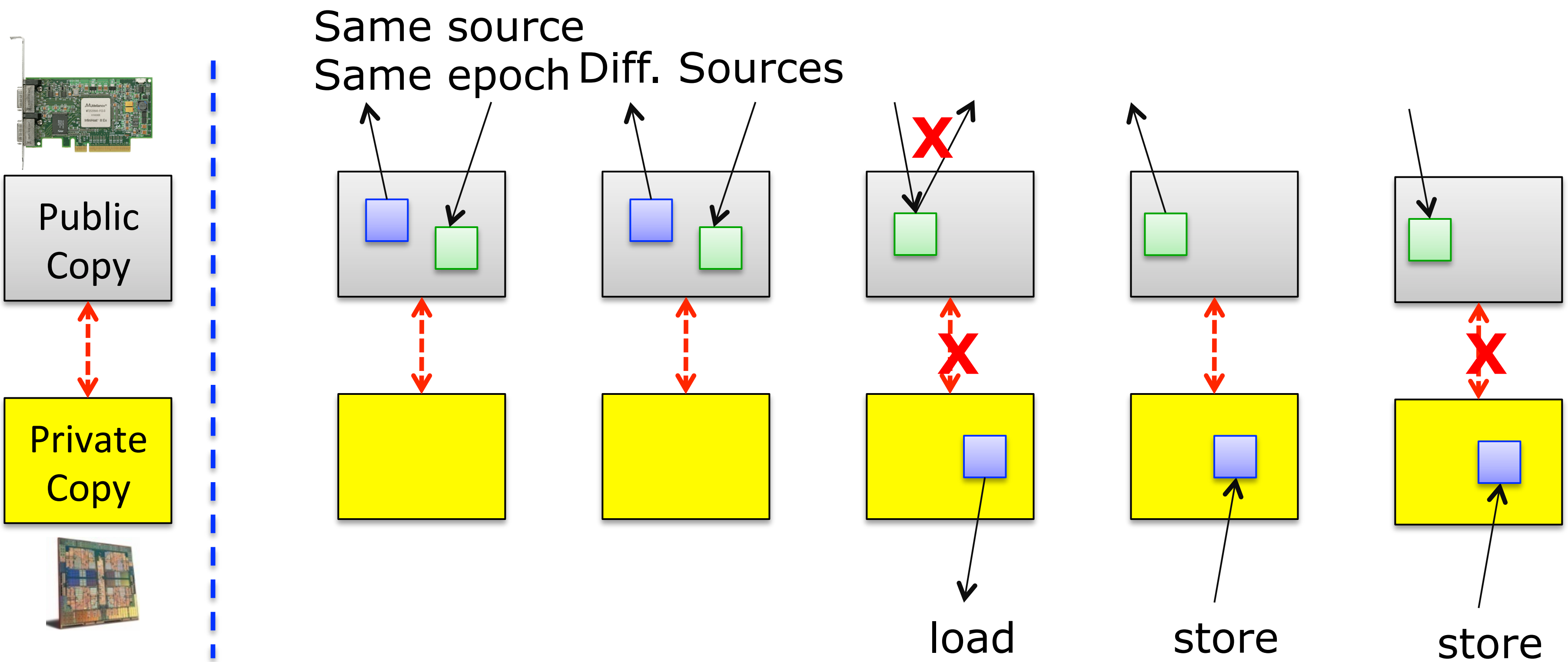
- RMA communication has low overheads versus send/recv
  - Two-sided: Matching, queuing, buffering, unexpected receives, etc…
  - One-sided: No matching, no buffering, always ready to receive
  - Utilize RDMA provided by high-speed interconnects (e.g. InfiniBand)
- Active mode: bulk synchronization
  - E.g. ghost cell exchange
- Passive mode: asynchronous data movement
  - Useful when dataset is large, requiring memory of multiple nodes
  - Also, when data access and synchronization pattern is dynamic
  - Common use case: distributed, shared arrays
- Passive target locking mode
  - Lock/unlock – Useful when exclusive epochs are needed
  - Lock_all/unlock_all – Useful when only shared epochs are needed

MPI RMA Memory Model

- MPI-3 provides two memory models: separate and unified
- MPI-2: Separate Model
  - ♦ Logical public and private copies
  - ♦ MPI provides software coherence between window copies
  - ♦ Extremely portable, to systems that don't provide hardware coherence
- MPI-3: New Unified Model
  - ♦ Single copy of the window
  - ♦ System must provide coherence
  - ♦ Superset of separate semantics
    - E.g. allows concurrent local/remote access
  - ♦ Provides access to full performance potential of hardware

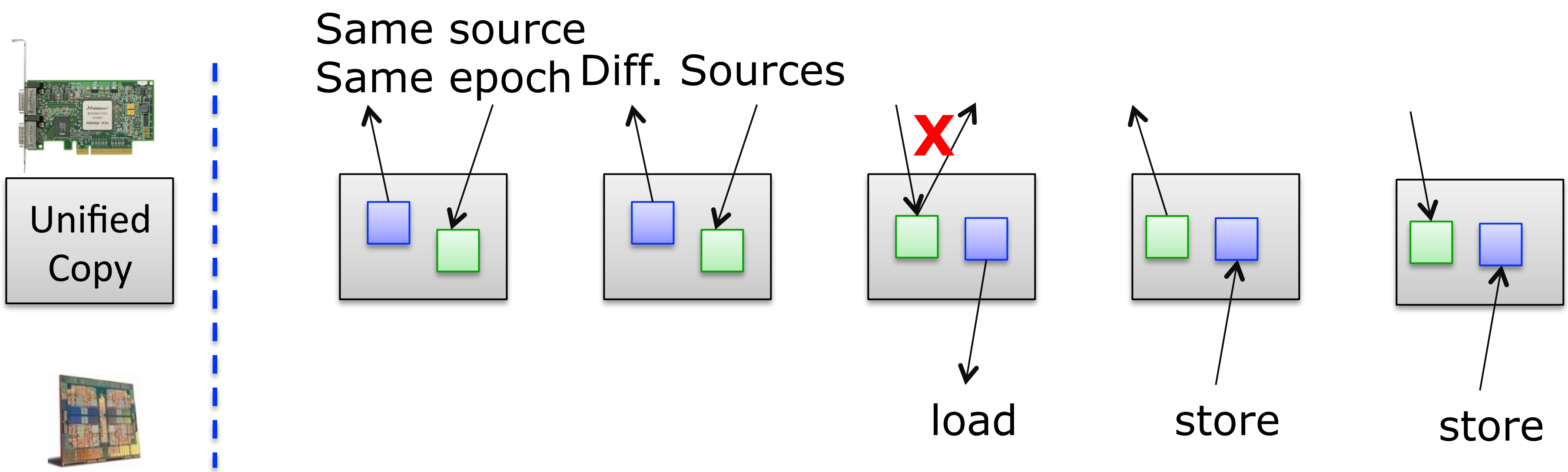


MPI RMA Memory Model (separate windows)



- Very portable, compatible with non-coherent memory systems
- Limits concurrent accesses to enable software coherence

MPI RMA Memory Model (unified windows)



- Allows concurrent local/remote accesses
- Concurrent, conflicting operations are allowed (not invalid)
  - Outcome is not defined by MPI (defined by the hardware)
- Can enable better performance by reducing synchronization

MPI RMA Operation Compatibility (Separate)

	Load	Store	Get	Put	Acc
Load	OVL+NOVL	OVL+NOVL	OVL+NOVL	NOVL	NOVL
Store	OVL+NOVL	OVL+NOVL	NOVL	X	X
Get	OVL+NOVL	NOVL	OVL+NOVL	NOVL	NOVL
Put	NOVL	X	NOVL	NOVL	NOVL
Acc	NOVL	X	NOVL	NOVL	OVL+NOVL

This matrix shows the compatibility of MPI-RMA operations when two or more processes access a window at the same target concurrently.

OVL – Overlapping operations permitted

NOVL – Nonoverlapping operations permitted

X – Combining these operations is OK, but data might be garbage

MPI RMA Operation Compatibility (Unified)

	Load	Store	Get	Put	Acc
Load	OVL+NOVL	OVL+NOVL	OVL+NOVL	NOVL	NOVL
Store	OVL+NOVL	OVL+NOVL	NOVL	NOVL	NOVL
Get	OVL+NOVL	NOVL	OVL+NOVL	NOVL	NOVL
Put	NOVL	NOVL	NOVL	NOVL	NOVL
Acc	NOVL	NOVL	NOVL	NOVL	OVL+NOVL

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Summary of MPI RMA

- MPI provides a powerful one-sided communication model
- General and precisely specified model
  - Complexity of the precision is sometimes confused with complexity for the user
    - There are simple models for the user that address most common use cases
- Implementations improving but many still poor, so test performance before using
- One more feature – MPI and shared memory – in the next lecture