

14-Oct-2021 - Google

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14-Oct-2021

5/5

Share

Set background

Clear frame

Reg

Wr

Head

nind/tail

not in list

ONLY DIRTY ①

Head Dirty ②

Head Fresh ③

④

⑤

Delete Self from list

Become Head ⑤

Dirty ②

Fresh ③

Only - Dirty ①

Quad

MFST

Contact Home add to list

Head

Head

Syam Sankar

NALABOLU SAN...

SU

SWATI UPADHYAY

IMIJUNGIA LON...

AS

ADITYA KUMAR S...

SARASWATULA P...

YK

YOGESH KUMAR

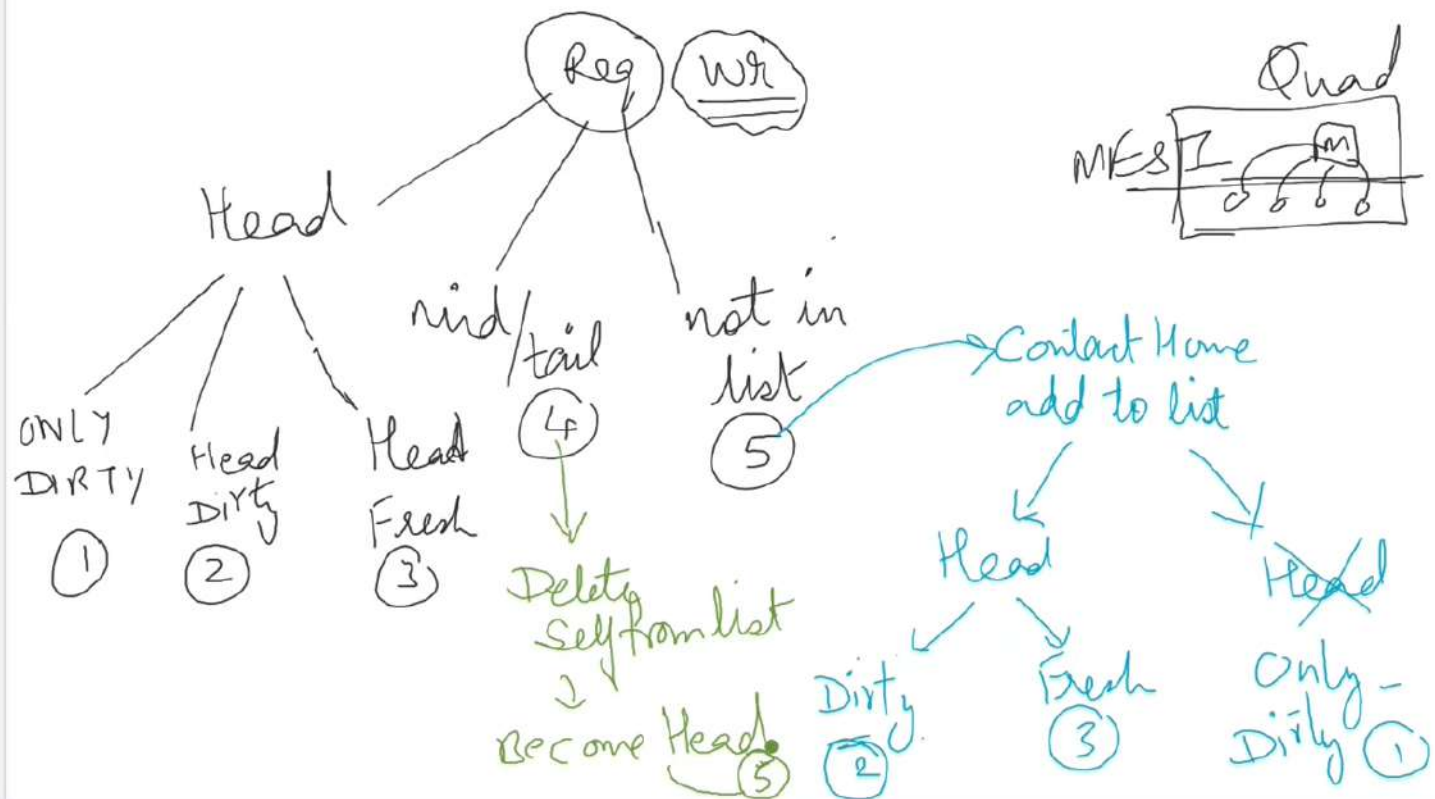
GR

GALI JAYA PRAKA...

TANVISH

Hemangee Kalpe...

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14-Oct-2021

Set background Clear frame

ONLY DIRTY
↓
start writing

Head Dirty
↓
in shavers
↓
purging list
↓
write

Head Fresh
↓
goto Home
↓
"gone"

Diagram illustrating a data flow or state transition:

- A box labeled "Head" is connected to a box labeled "1" (with "in" above it) and a box labeled "2" (with "adv" below it).
- Box "1" is connected to box "2" via a double-headed arrow labeled "adv (pt)".
- Box "2" is connected to a box labeled "in shavers" via a double-headed arrow.
- Box "in shavers" is connected to a box labeled "purging list" via a double-headed arrow.
- Box "purging list" is connected to a box labeled "write" via a double-headed arrow.
- Box "write" is connected to box "2" via a double-headed arrow.

75% (2:16) Sat, October 16, 11:14

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RAHUL KUMAR

VA
VARHADE AMEY...

Hemangee Kalpe...

Handling Write Requests

- Requestor has following possibilities
 - Is at Head of sharing list: (1) ONLY_DIRTY, (2) HEAD_DIRTY, (3) HEAD_FRESH
 - (4) Not in sharing list, (5) In sharing list but not at Head
- (1) **ONLY_DIRTY** : OK can start writing immediately
- (2) **HEAD_DIRTY** and is at Head of sharing list. Sequentially invalidate all sharers then write
- (3) **HEAD_FRESH**
 - Request sent to home to change state to GONE
 - Make state to HEAD_DIRTY. Then as above
- (4) **Not in sharing list**
 - Allocate entry in (local) cache
 - Become Head by communicating with Home. Then do as above
- (5) **In sharing list, but not Head**
 - Remove self from list. Request/Response with neighbours (details later)
 - Add self to Head (as above). Then do as above



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Purging the list

- Block is HEAD_DIRTY: Purge the sharing list
- Purge in serialised manner
- Send inv request to next-node, which rolls itself out from the list and sends back to head the next-pointer
- The head sends similar request to this next pointer and so on ...
- Head node stays in pending state till purging completes. Therefore new attempts to add to the list go in the pending list
- OPTION: to reduce the number of network transactions in the critical path, each node can forward the inv to next-node and ACK the previous
- Correct. But not part of SCI standard. This way it distributes the state of invalidation progress and hence complicates the protocol-level recovery from errors

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Purging the list

- Writer is HEAD_FRESH
 - Goes to pending state ; goes to Home; Home changes from FRESH to GONE and replies to writer
 - Writes goes to another pending state and start purging of the list
- Race condition:
- HEAD_FRESH goes to home to request change state to GONE
- But finds home state \neq FRESH but points to a newly queued node (which got there in the meantime) and this new node is about to contact the writer
- Home sends some kind of NACK to writer
- Writer will receive request from new-node to link with it
- The writer will then delete itself from list and later try to re-attach at Head to request write-operation



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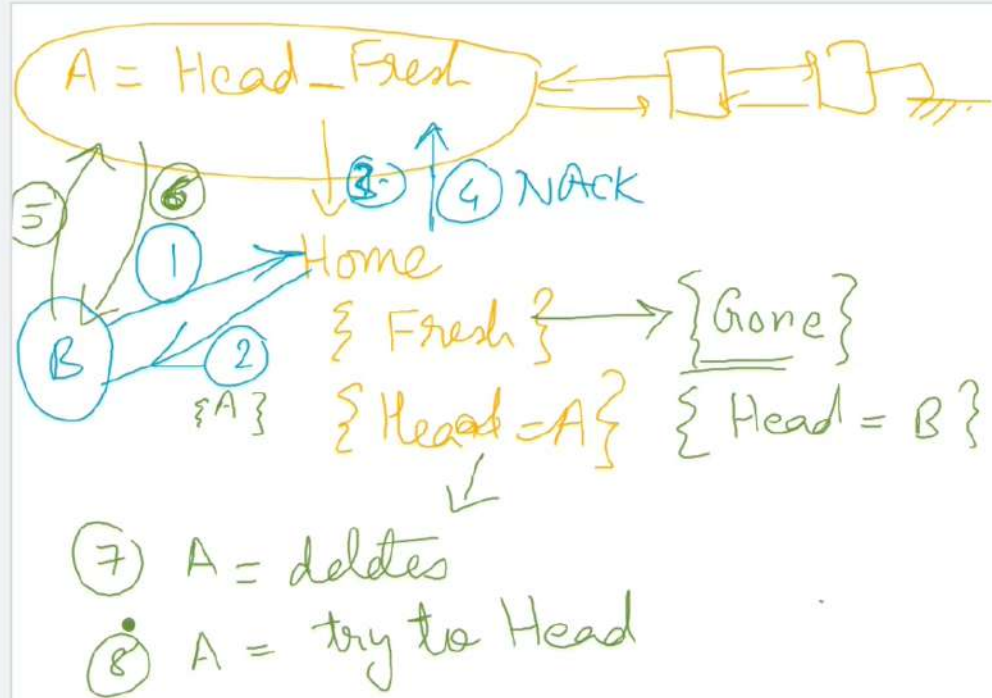
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SARASWATULA P...	YOGESH KUMAR
	
GALLI JAYA PRAKA...	TANVISH
	
RAHUL KUMAR	VARHADE AMEY...
	
AMIT	IMIJUNGLA LON...
	
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Wr-backs/replacement: Mid

- Updating memory with data + delete self from sharing list (=roll-out) : Mid/Tail - or - Head
- MID
 - Set state to pending
 - Send request to neighbours to update pointers
 - What if neighbour is pending?
 - i.e. trying to delete itself => priority given to tail-side node
 - The block is marked "invalid" in the cache
 - Other nodes in the list do not have any change. Except if there are 2 nodes: then the head becomes ONLY_DIRTY or ONLY_FRESH as appropriate



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14-Oct-2021
7/7
Share
Set background
Clear frame

A = Head_Fresh

(5) → (6) → (1) → (B) → (2) → Home

(4) NACK → (3)

Busy?

{ Fresh } → { Gone }

{ Head = A } → { Head = B }

(7) A = deletes

(8) A = try to Head

↓ node at a time

↓ race priority

↓ Tail side

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68% (1:57) Sat, October 16, 11:28

write-back/replacement: Head

- Entry dirty then write-back / Entry is clean then replacement
- Head puts itself in **pending state** and send **message to downstream** node
- Downstream node puts backward pointer to Home node and changes state appropriately and replies to replacer
 - **TAIL_VALID => HEAD_DIRTY**
 - **MID_VALID => HEAD_DIRTY**
 - **MID_FRESH => HEAD_FRESH** (depends on state of original Head node)
- Replacer (old head) sends **transaction to Home** telling to link to new Head
 - Home updates head pointer to the new Head
 - State change is not needed at Home node
 - Home replies to replacer
- After receiving reply form Home, the replacer sets its block to **Invalid state**
- **If replacer is the only node in the list**
 - **It only has to communicate with Home node**



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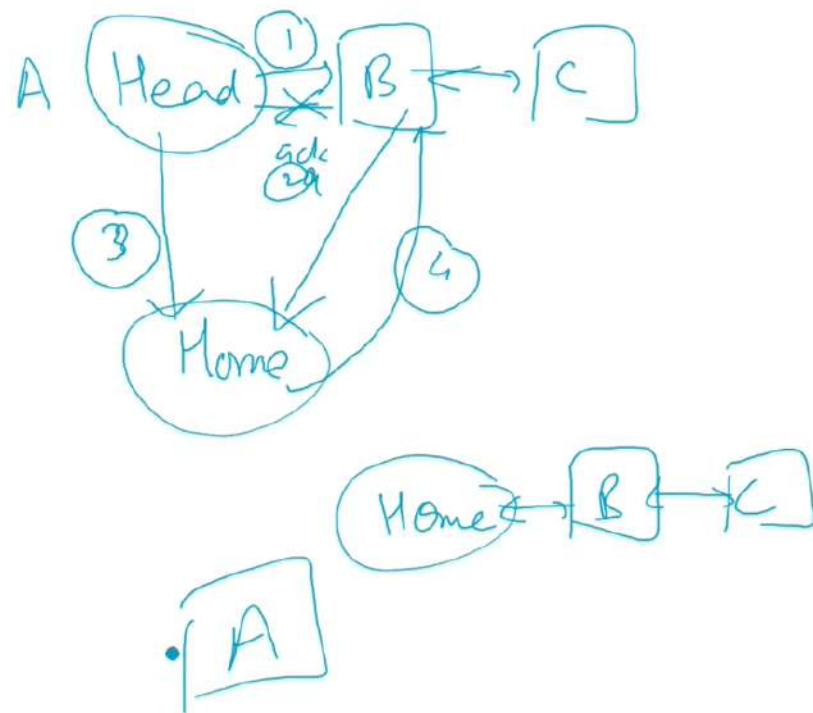
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write-back/replacement: Head

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- wb {*
- TAIL_VALID => HEAD_DIRTY ✓
 - MID_VALID => HEAD_DIRTY ✓
 - MID_FRESH => HEAD_FRESH (depends on state of original Head node)
- dup*

- Replacer (old head) sends transaction to Home telling to link to new Head
 - Home updates head pointer to the new Head
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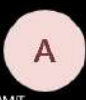
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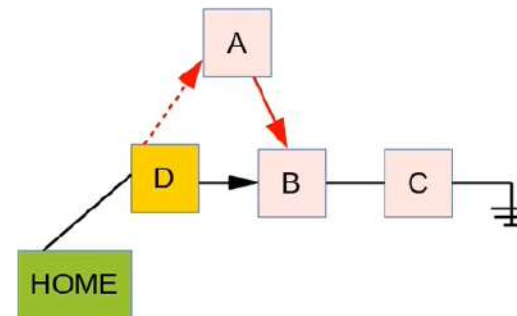
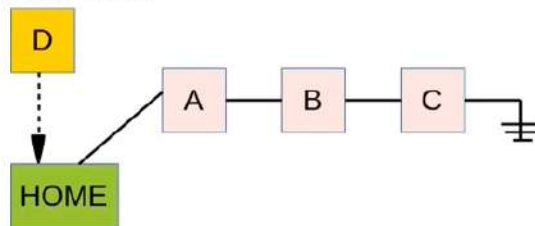
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Race condition

- When it reaches home-node, home state has changed and therefore home send response like a NACK
- Eventually Head will get the request from the new-node which tries to link with head
- Head then responds to new-head by linking it with next neighbour and thus deletes itself



- To serve write-miss: replace old block + load new
 - In bus based load new first and put old in wr-buffer
 - In SCI due to sharing-list roll-out first then load new-block, as block being deleted has data and also pointers to nodes in the sharing-list



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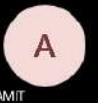
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8 / 8

Share

Set background

Clear frame

The diagram illustrates a linked list structure and pointer manipulation. At the top, a node labeled 'Head' (circled) has a pointer to node 'B' (boxed). Node 'B' points to node 'C' (boxed). A circled '1' is next to the arrow from 'Head' to 'B', with a circled '2' and '3' below it. A circled '4' is next to the arrow from 'B' to 'C'. Below 'Head', a circled '3' points to a node labeled 'Home' (circled). To the right, text reads 'Head_Dirty = B' with an arrow pointing to a circled 'Valid' node, which has an arrow pointing to 'B'. Below this, 'Mid_Valid = B' is written. At the bottom, a node labeled 'Home' (circled) points to node 'B' (boxed), which points to node 'C' (boxed). A separate box labeled 'A' is at the bottom left.

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9/9

Share

Set background

Clear frame

How = Fresh

Write
Home → Gone

ONLY - DIRTY
TAIL - VALID

Head Dirty

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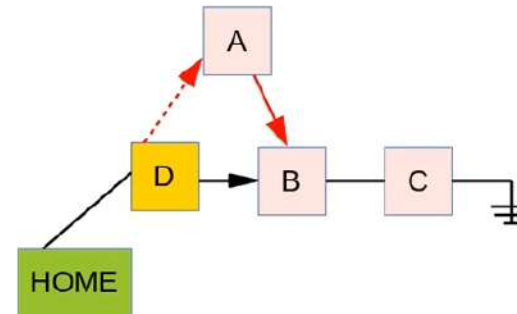
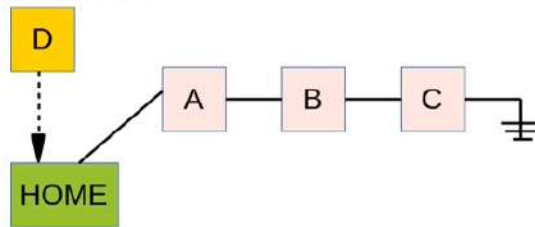
AMIT

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Race condition

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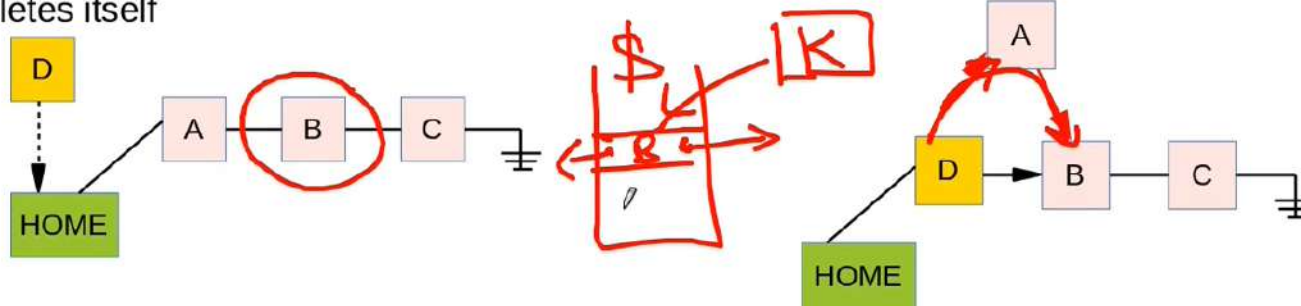
RATHOD SAINATH



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Serialisation

- Home node determines the order in which cache misses to a block are serialised
- There is no busy-state at home
- Home accepts each request and either
 - It serves itself ... Satisfies request wholly by itself, or
 - Directs to the node that it sees as Head: either true-head or pending-head
- Before re-directing request, it changes head pointer to new requestor. So that all subsequent requests will go to the new-head (or pending head!)
- If a request is not satisfied, the node remains in the pending list and awaits its turn
- Nodes in pending list obtain access to the block in FIFO order, ensuring that the order in which they complete is indeed the same as that in which they first reached the home
- In case Home NACKs a request, this request never succeeds in the current form and will send a new request. Old request is cancelled and new request is serialised



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Deadlock, Livelock, Starvation

- Distributed pending list holds waiting requests at the requesting cache itself
 - No separate hardware queue at home node
 - No limited buffer
 - => No deadlock
- Strict req-response
 - As no NACK there is No contention due to race condition. They simply join the pending queue and all requests make progress
 - => No Livelock
- List mechanism ensures that request are ordered in FIFO order (as they reach home)
 - => No Starvation
- A node can be part of number of pending lists. This number is equal to the number of outstanding requests. The space for the pointers is already with the cache, hence no extra storage overheads.
 - Pending node cannot replace until it becomes normal node



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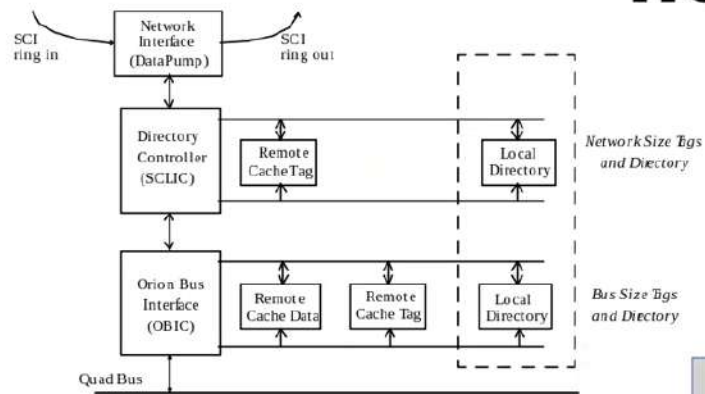


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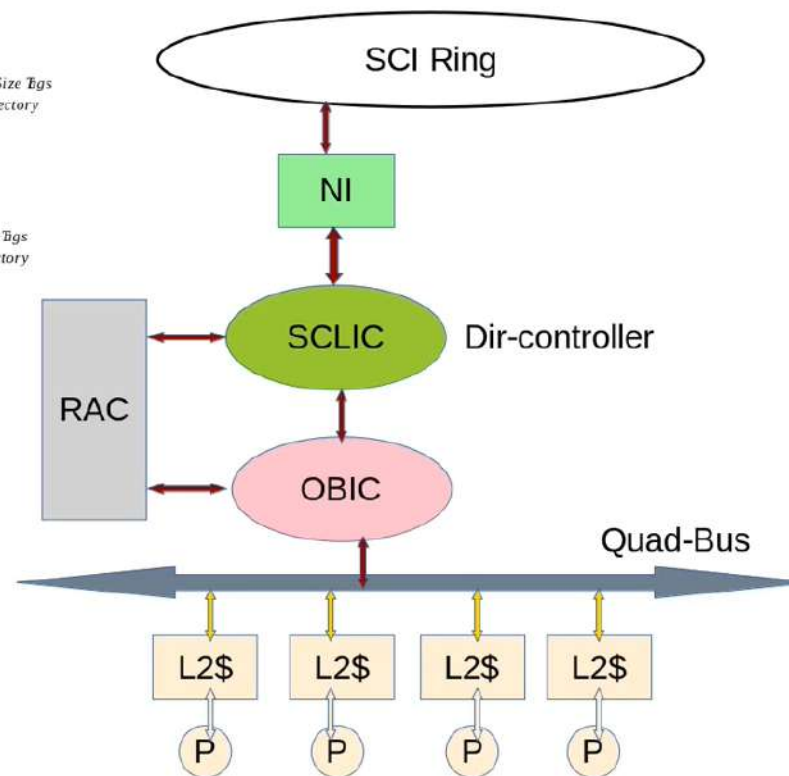


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Protocol Interactions with SMP-node



- How to combine the RAC-level SCI protocol with intra-cluster protocol (on the Quad bus)



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Interactions for Read-request

- Processor level read-miss in its L2-cache goes on Quad-bus
- All caches snoop bus and OBIC bus controller also snoops Quad-bus
- If request can be satisfied by RAC, i.e. RAC has the cache block and Dir-state is OK, then serve request locally
- The local memory or another local-cache inside the cluster can also serve the request.
 - There is provision to wait for snoop-result delays. Snoop results come after fixed delay of 4 cycles. If not ready then asserts a stall of another 2 cycles and this wait of 2 cycles continues until results are ready.
 - All local caches follow MESI
 - Quad-bus = in-order response



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Interactions for Read-request

- If request must be propagated off-node:
 - OBIC detects and intervenes by sending a “deferred response” signal on Quad bus
 - Upon which Quad-bus leaves the request-pending and leaves in-order response for this request and starts serving new-(internal)-requests
- OBIC passes request to SCLIC to start the directory protocol
- When remote response comes back, SCLIC transfers it to OBIC
 - Then OBIC places response on Quad-bus and completes the deferred transaction
- NOTE: to have a bus-system to become part of a larger system it must be split-transaction-bus for performance + correctness
- Else
 - Bus held up for entire duration of remote transaction
 - Therefore not allowing local misses and not serving incoming requests
 - Which may result in potential deadlock



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Interactions for Write-request

- Same set of actions as read
- OBIC snoops the state of block in the RAC
 - Block is owned by **local** quad or
 - Request must be sent **outside**
- Node has to be put at **head** of sharing list, all nodes **invalidated** and then the write can be performed. All this is taken care by the SCLIC
- When SCLIC is done, it puts the **response** on the **quad** bus (via the OBIC) which completes the operation



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Interactions for Write-request

- Limitations
 - A locally allocated block, i.e. its address maps to local memory and it is cached remotely and modified there
 - When we bring this block to cluster to serve read/write-miss, the response is put on the bus.
 - Here, the block must also be updated in local memory
 - But local memory design cannot accept data from deferred transactions, as it is not designed that way to understand deferred responses
 - OBIC has to use special action to update local memory before releasing the bus
 - If two read-exclusive request for same block come on Quad-bus back-to-back
 - One goes to SCLIC and other is NACKed it must retry
 - Ideally the second request should have been buffered and the response of the first could have been used by the second request (in an appropriate state)



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Serialisation

- (1) For locally allocated blocks
- Earlier we said serialisation is done by home-node in the order of requests accepted
- Therefore home has to serialise incoming transactions and also transactions from local processor on Quad-bus
- e.g. home-dir-state = HOME
 - No remote node has cached the block, BUT the block may be cached and even modified in some local-cache (inside the Quad)
 - To serve an incoming request for a block that is dirty in local cache we need to go on the Quad bus and cannot be handled entirely by SCLIC and OBIC
 - Similarly, an incoming request that makes home state (Home or FRESH) => GONE must be put on the Quad bus so that copies in the processor caches are invalidated
 - Since both incoming requests and local misses to data at the home appear on the quad bus, it is natural to let this bus be the actual serialising agent
 - The Quad bus at the Home node is the serialising agent



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10 / 10

Share

Set background

Clear frame

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Serialisation

- (2) Issues of serialisation of the requesting quad for remotely allocated blocks
- Activities within a Quad relating to remotely allocated blocks are serialised at the local SCLIC and not at the bus
- (i) Request from local processor for a block in the remote cache AND (ii) incoming requests from the SCI interconnect for the same block are serialised at local SCLIC
- Also, SCLIC (locally) serialises outstanding invalidations at a requestor and new incoming requests



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10 / 10

Share

Set background

Clear frame

```
graph TD; SCI[SCI] --- RegB((Reg B)); RegB --- 1((1)); 1 -- inv --> SCLIC([SCLIC]); SCLIC --> GBIC([GBIC]); GBIC --- 2((2)); 2 -- Read X --> GBIC; GBIC <--> QB[Quad Bus]; B[B] -- RD -> WR --> QB;
```

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SWATI UPADHYAY

ADITYA KUMAR S...

YK

IMJUNGLA LON...

YOGESH KUMAR

RATHOD SAINATH

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Hemangee Kalpe...

14-Oct-2021 - Google

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The diagram illustrates a hardware architecture with the following components and connections:

- Processors:** P1, P2, and P3 are represented by boxes. P1 is at the bottom, P2 is at the top right, and P3 is at the top left.
- Register:** A circle labeled "Reg B" is connected to P3 and P2.
- SC1:** A large oval labeled "SC1" is connected to P3, P2, and the Register.
- Serialising entry:** A blue box labeled "Serialising entry" contains two ovals: "SCLIC" and "GBIC".
- Quad Bus:** A horizontal double-headed arrow labeled "Quad Bus" connects the Serialising entry to P1.
- Connections and Annotations:**
 - An arrow labeled "1 inv" points from the Register to the SCLIC oval.
 - An arrow labeled "(2) Read X" points from the SCLIC oval to the GBIC oval.
 - An arrow labeled "RD → WR" points from the GBIC oval to the Quad Bus.
 - Handwritten notes on the right side: "P3 → inv", "P3 → WR-B-P3", and "P1 → WR-B" (circled).

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