Improving forwarding logic in Slurm

Slurm 2014 User Group

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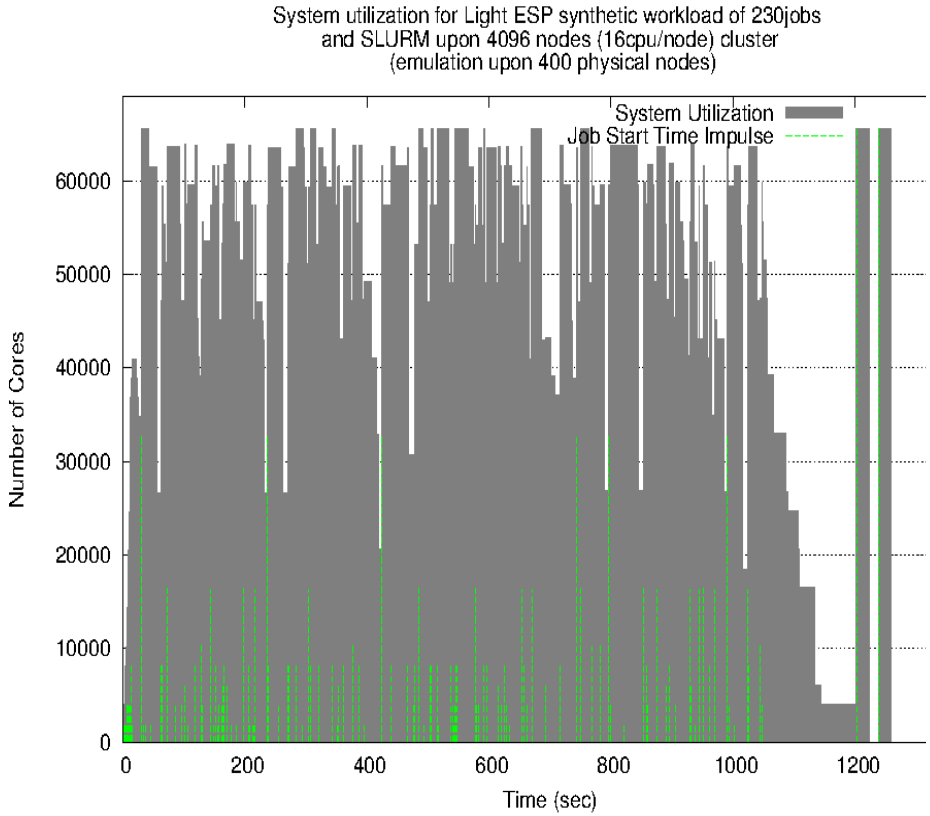
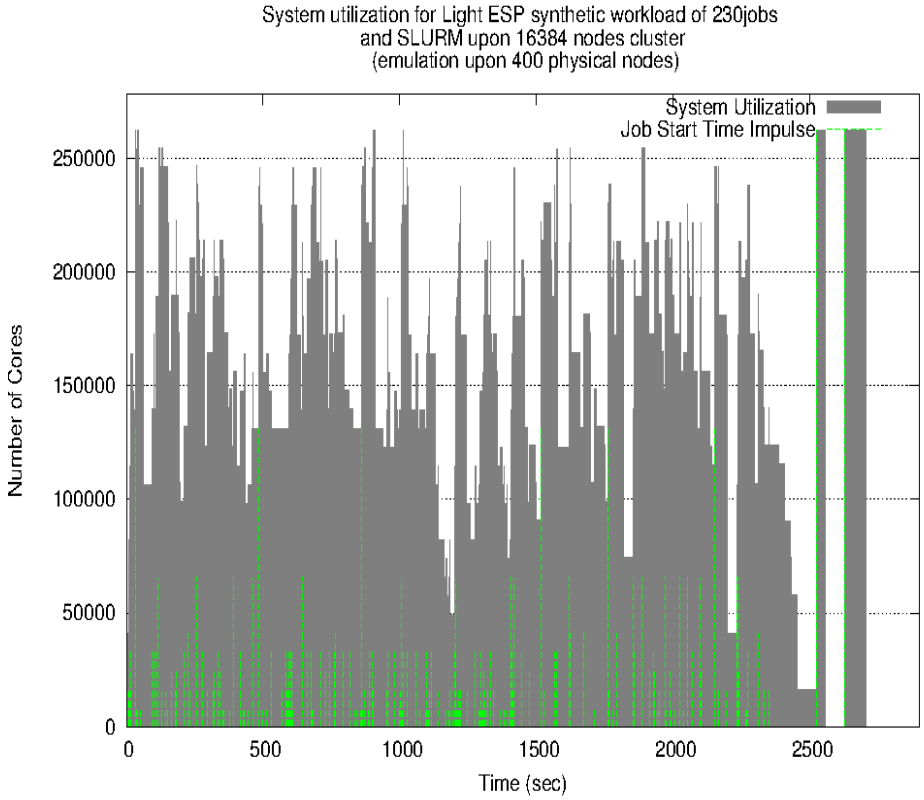
Motivations

- Upcoming "multi-petaflop" systems will have thousand of nodes interconnected by large scale high-speed networks
- SLURM may have to pass by the same high-speed network used by applications, hence there are two issues:
    - Internal communications mechanisms in SLURM do not take into account the underlying network topology
    - Reverse communications (from slurmd to slurmctld) can be an important bottleneck with larger number of nodes [1]

[1]Yiannis Georgiou, Matthieu Hautreux: Evaluating Scalability and Efficiency of the Resource and Job Management System on Large HPC Clusters. JSSPP 2012: 134-156

Reversed communications scalability bottleneck





- Performance Degradation visible in the increase of turnaround time and stretching of the diagram (detailed analysis in [1]).
- Every node involved in a job sends its own completion message directly to the controller :
  - too many EPILOG_complete RPCs
  - increase of processing time on the controller

Goals of the project

- Re-factoring of the communication logic of Slurm in order to provide **partially deterministic direct and reverse tree communications**.
  1) Increase performances by better handling the **mapping** between the **trees of communication used by SLURM** and the existing **physical network** connections.
  2) Provide the ability to **aggregate messages directed to the controller** to limit the amount of RPCs to be handled simultaneously when possible.

Overview

- Two new features have been implemented.
- Route Plugin (already in 14.11)
- Messages Aggregation (to appear in 14.11 or 15.xx)

Route Plugin

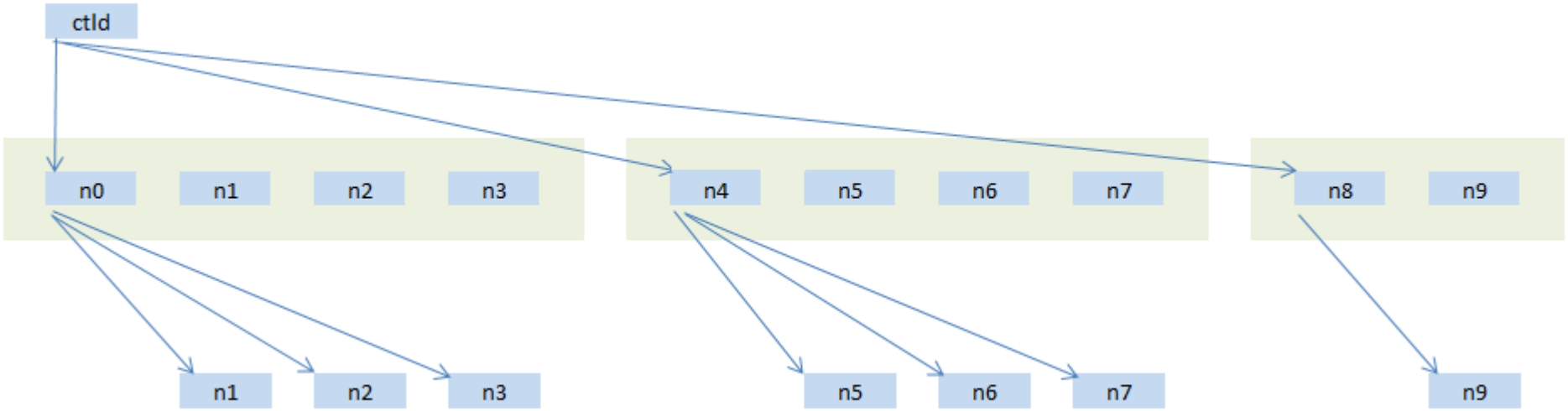
- Provides an opportunity to choose message forwarding nodes based on patterns other than the TreeWidth Parameter.
- Can off load some communication overhead from slurmctld.
  - A side effect may be more message hops and higher latency.
- Plugin Implementations
  - RoutePlugin=route/default
  - RoutePlugin=route/topology

Route Plugin -- default

- Splits a list of nodes to send a message into sublists based on tree width.
- Sent the message to at most treewidth nodes.
- If the number of nodes is > treewidth, include in the message header a list of node that the forwarding node with send the message.
- Receiving node may also split its list into sublists.
- Message forwarding is identical to current implementation

Route Plugin – default (2)

- Message Forwarding Between Nodes
  - TreeWidth=3

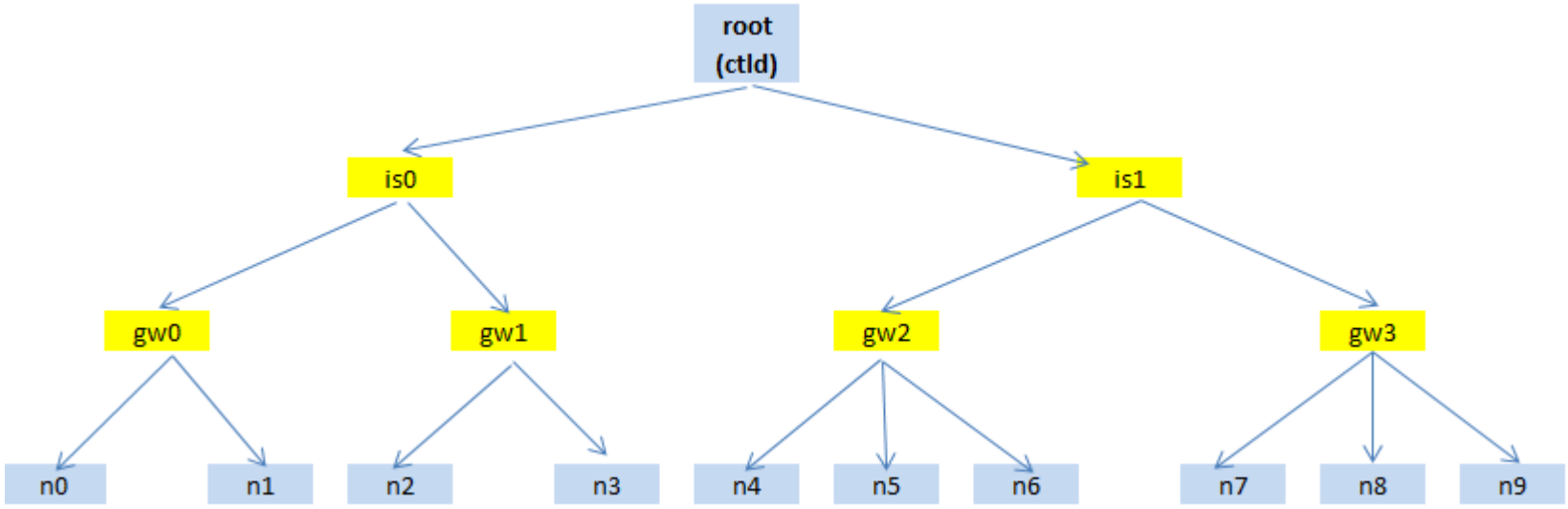


Route Plugin -- topology

- Split message list into sublists based on switch topology in topology.conf (requires topology/tree)
- (message sent to first node on switch, and its message list is all nodes that are reached by that switch)
- Messages forwarded to nodes that are ‘close’
- Slurmctld will usually forward to fewer nodes so will have less overhead handling comm.

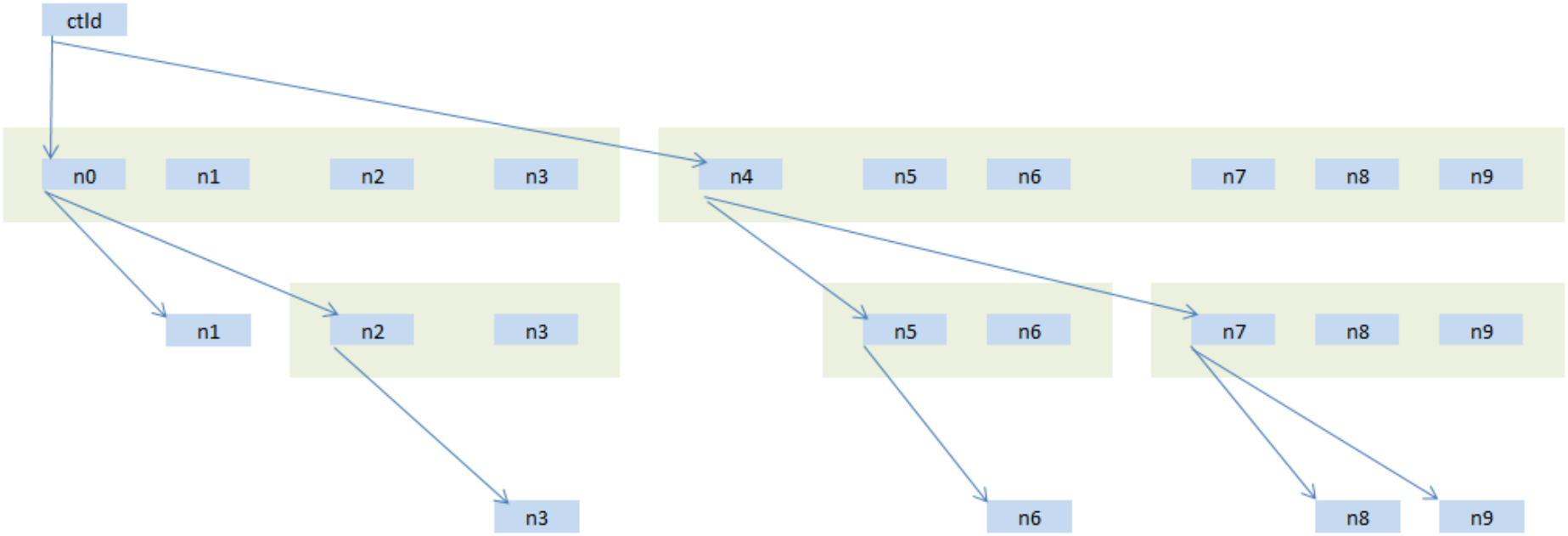
Route Plugin – topology (2)

- `# topology.conf`
- `SwitchName=root Switches=is[0-1]`
- `SwitchName=is0 Switches=gw[0-1]`
- `SwitchName=is1 Switches=gw[2-3]`
- `SwitchName=gw0 Nodes=trek[0-1]`
- `SwitchName=gw1 Nodes=trek[2-3]`
- `SwitchName=gw2 Nodes=trek[4-6]`
- `SwitchName=gw3 Nodes=trek[7-9]`



Route Plugin – topology (3)

- Message Forwarding Between Nodes



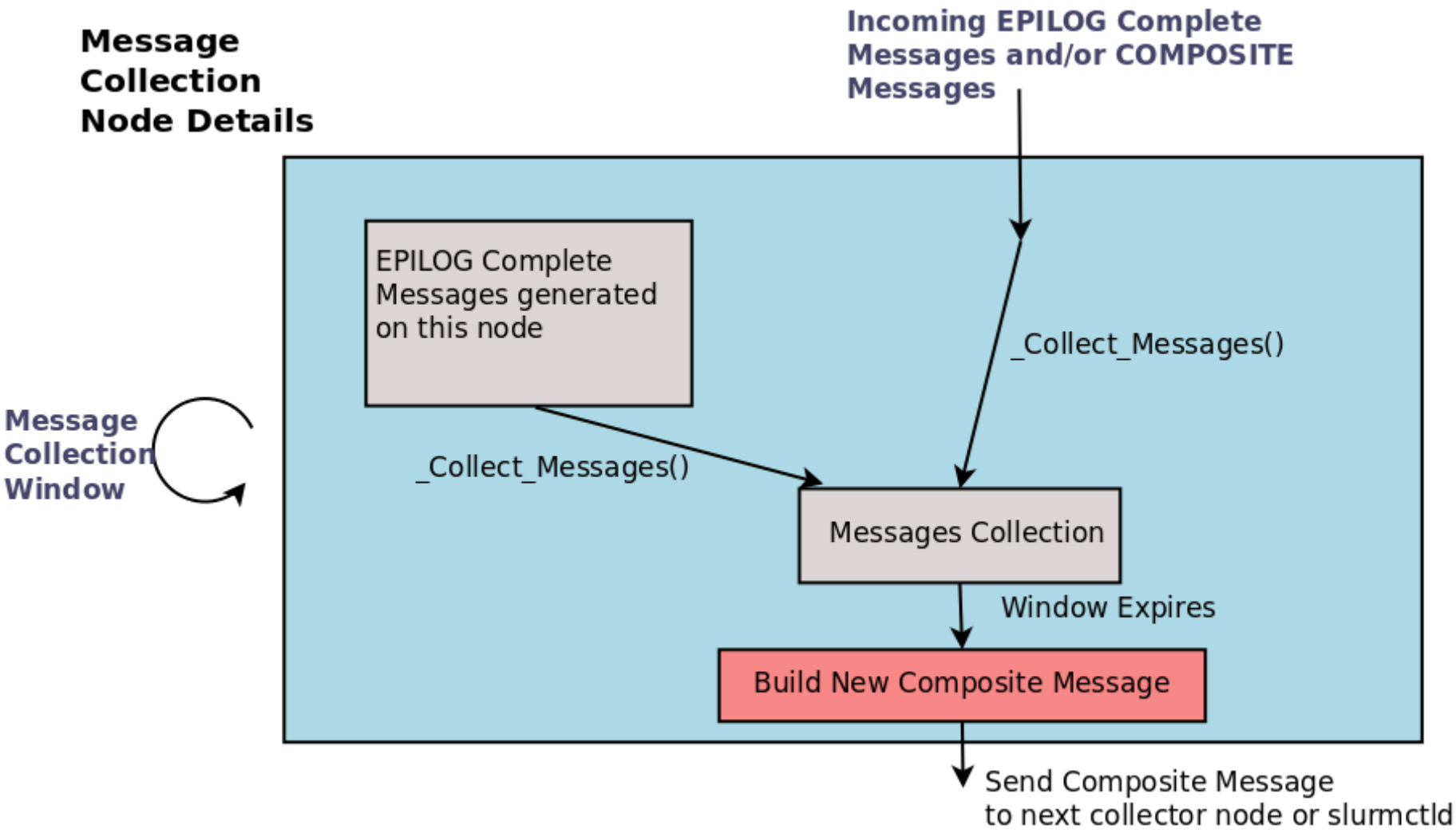
Message Aggregation - Overview

- Resolves problem by **aggregating epilog complete messages** into a smaller number of composite messages, reducing the number of incoming TCP connections to serve.
- Essentially the reverse of the message forwarding/fanout mechanism used to reduce the load on the controller for broadcast messages.
- Will be enhanced in the future to support additional message types and destination nodes (not just the controller), and to support message responses.

Message Aggregation - How It Works

- If a compute node epilog script is configured (*Epilog*= parameter in slurm.conf), or a job is killed (due to walltime or scancel) an **epilog complete message** is generated on each compute node for each job using that node.
  - Without message aggregation:
    - Each epilog complete message is sent directly to slurmctld on the management node.
  - With message aggregation:
    - Epilog complete messages are routed through a series of **message collector nodes**.
    - On each collector node, epilog complete messages received during a defined **message collection window** are collected and packaged inside a new **composite message** type.
    - When the window expires, the composite message is sent to the next collector node on the route to slurmctld.

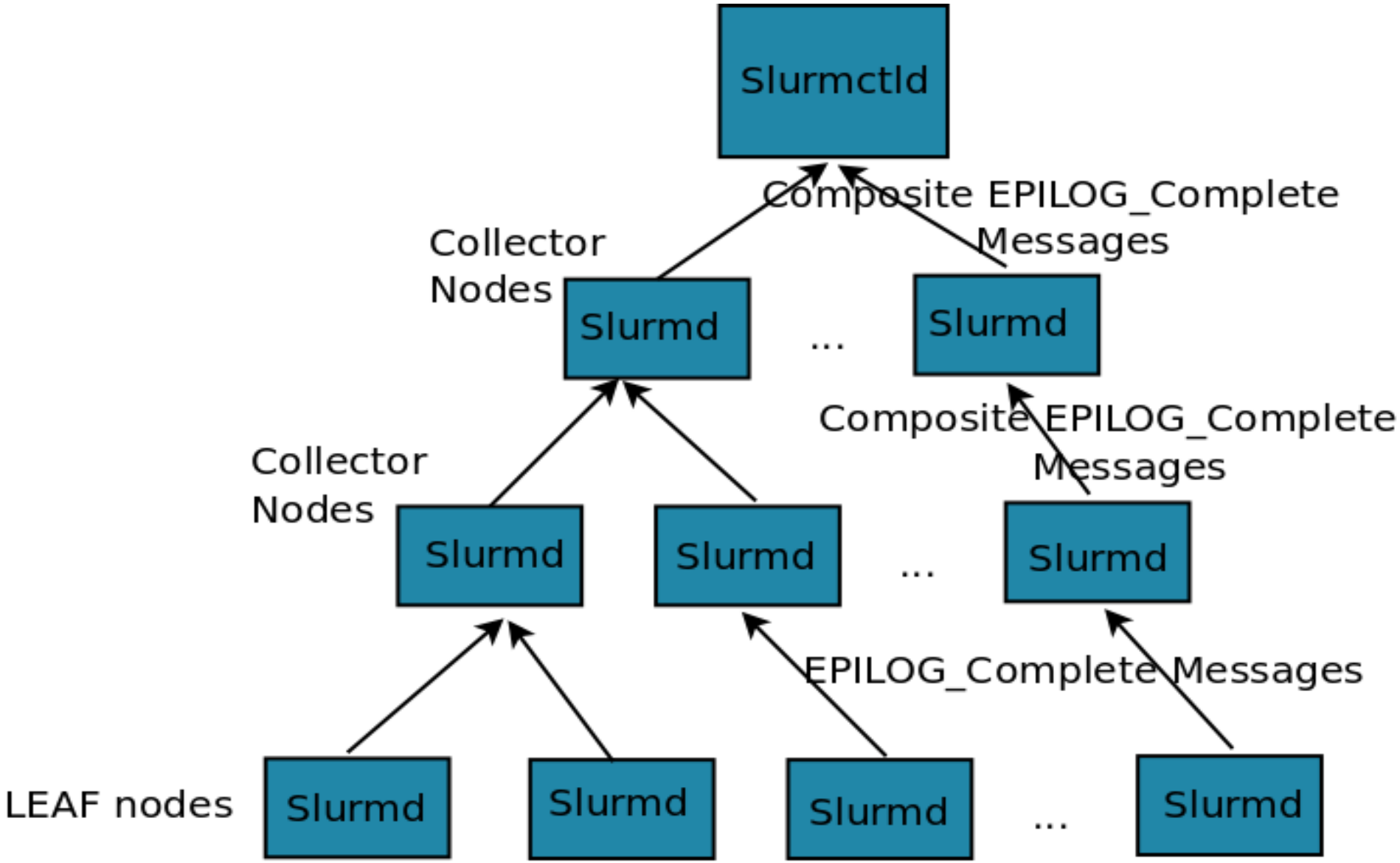
Message Aggregation - How It Works



Message Aggregation - How It Works

- The message collection window size = maximum number of messages plus maximum elapsed time.
  - A window expires when either the maximum messages or maximum time is reached, whichever occurs first.
  - A new window is started when the first epilog complete message or composite message is received following expiration of the previous window.
- The routing used for message aggregation is provided by the **Route plugin**.
  - This determines the number and identity of the message collector nodes and the number of message collection “hops” between each compute node and the management node.
- When slurmctld receives a composite message, it extracts each epilog complete message and processes it as if it had been sent directly from the node that generated it.

Message Aggregation Topology: Example



Message Aggregation - Limitations

- The message aggregation feature involves a trade-off between the amount of aggregation and message delay.

- A larger message collection window size and/or a larger number of message collector nodes will increase the amount of aggregation (reducing the load on the controller) but will also increase message delay at collector nodes (delaying job completion).

- The feature is recommended mainly for systems subject to the job termination bottleneck problem. Experimentation may be required to determine the optimum message collection window size and number/layout of message collector nodes.

Message Aggregation - Configuration

- Disabled by default. Enabled with new slurm.conf parameter **MsgAggregationParams**.
- MsgAggregationParams defines the message collection window size as a maximum number of messages and maximum time (in milliseconds). Example:

```
MsgAggregationParams=WindowMsgs=10,WindowTime=100
```

- The Route plugin and associated parameters determine the number and identity of the message collector nodes.
  - Either: `RoutePlugin=route/default with TreeWidth=`*n*
    With this option, the message aggregation route is the reverse of the message forwarding route used for broadcast messages (messages sent from controller to multiple compute nodes).
  - or: `RoutePlugin=route/topology withTopologyPlugin=topology/tree and a topology.conf file.`
    With this option, the message aggregation route is defined by the node topology configuration in topology.conf.

Experimentation Testbed

- Performance evaluation experiments followed the same guidelines as in [1].
  - Emulated environment: 5040 emulated nodes upon 16 physical nodes
  - Light-ESP workload: 230 jobs with adaptable sizes according to size of the cluster
- Tested 3 different scenarios with the following configurations:
  1) No route plugin, no message aggregation
  2) Route plugin/default with message aggregation 100msgs in 10msec
  3) Route plugin/default with message aggregation 500msgs in 1sec

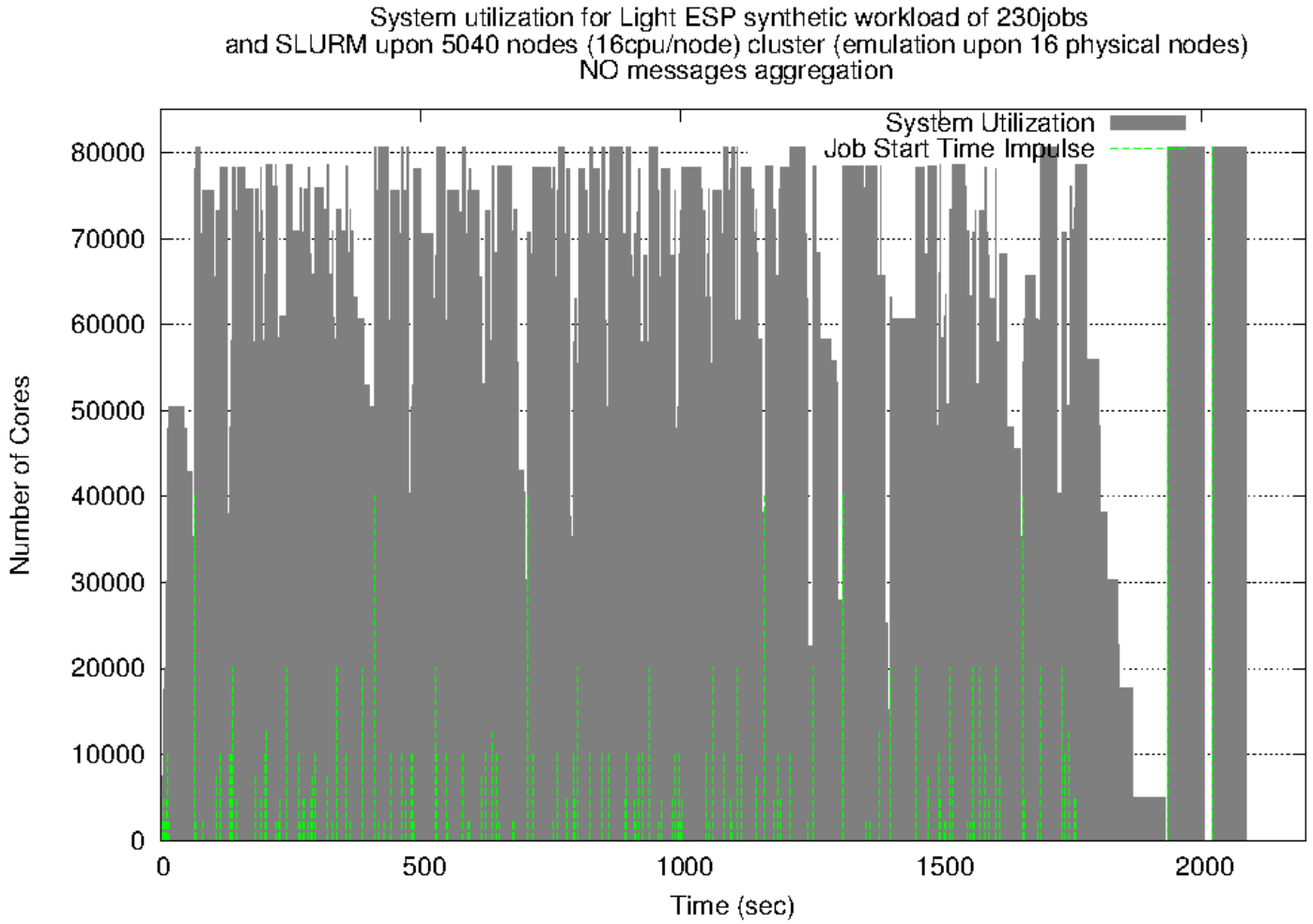
Experimentation Results - TCP connections

- Measured number of EPILOG_complete messages during the workload and number of COMPOSITE messages:

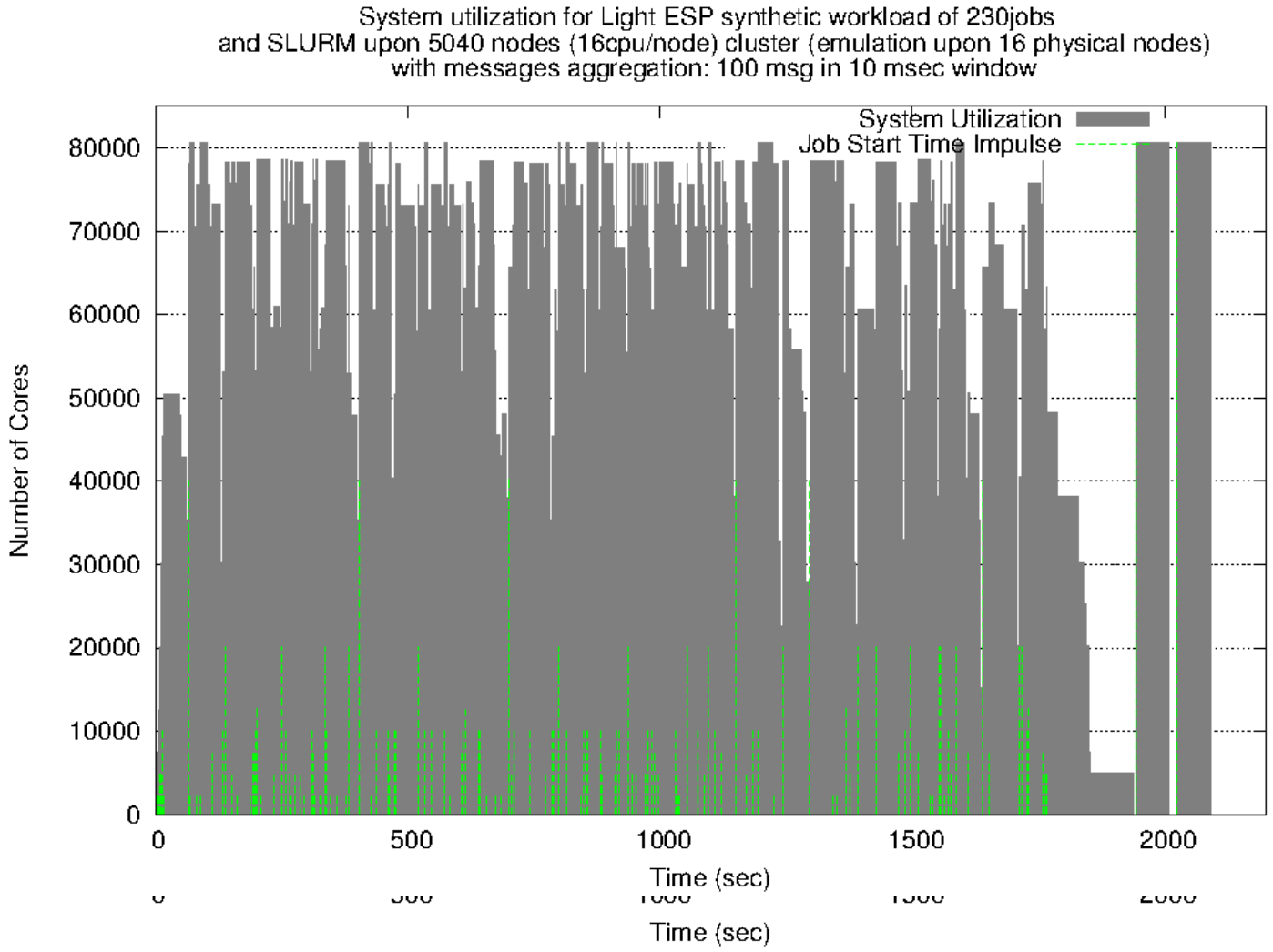
	Total number of EPILOG	Total number of Composites	Total nested Composites	Average EPILOG in Composites	Median EPILOG in Composites	Max EPILOG in Composites
NO MSG Aggregation	**115358**					
100MS in 10 msec	115486	**35986**	12570	3.2	4	29
500MS in 1s	115443	**5162**	1814	22,4	16	52

- A workload of 230 jobs that lasts about 1200sec produced about **115500 EPILOG complete messages**
- The message aggregation technique **diminished significantly** the **number of TCP connections** that the controller has to serve

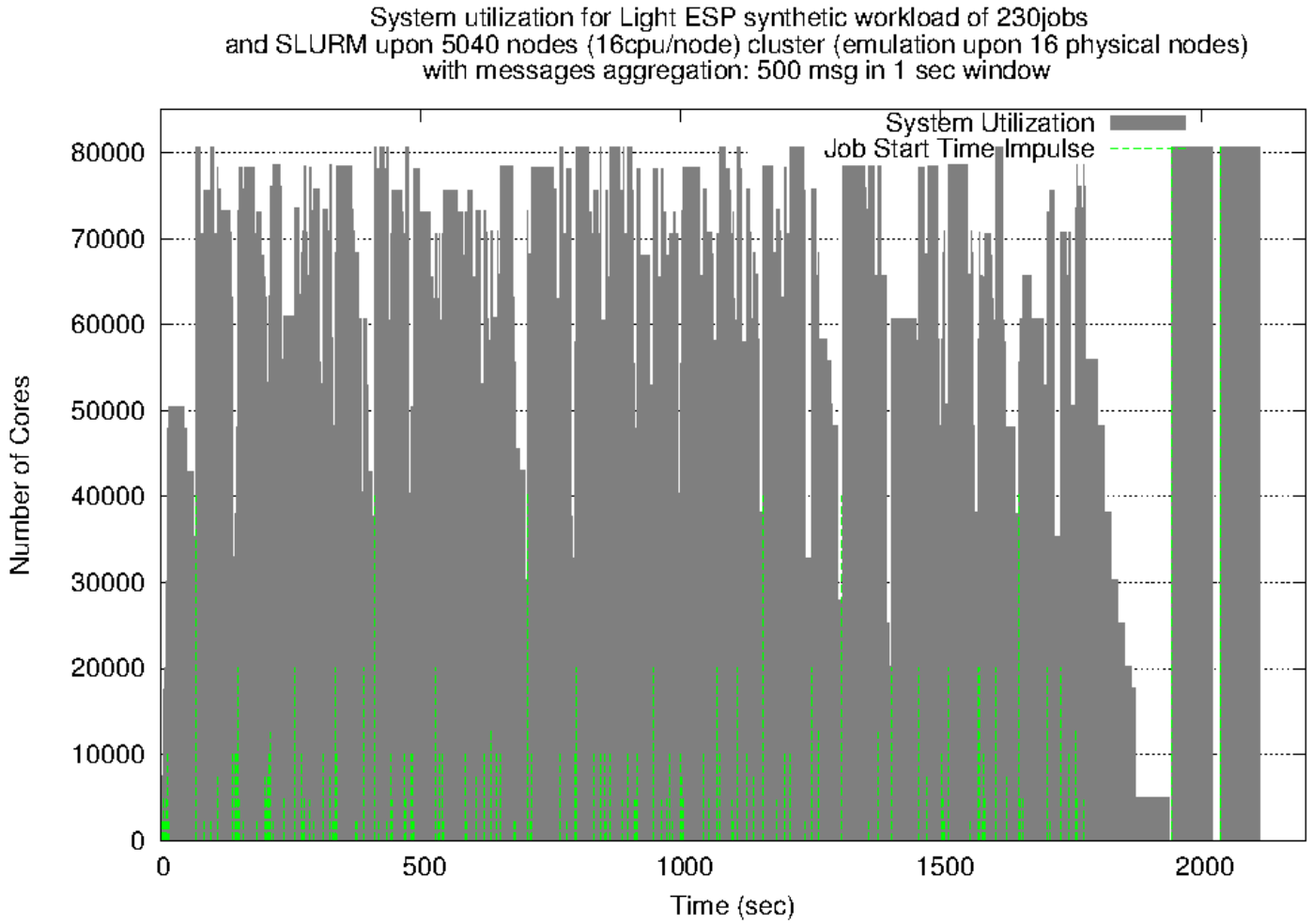
Experimentation Results - Processing time
NO Message Aggregation



Experimentation Results - Processing time
With Message Aggregation 10ms window



Experimentation Results - Processing time
With Message Aggregation 1s window



Discussion

- **Absolutely** no improvement at all in overall turnaround time of the whole workload!!
  - We can even observe a slight improvement in overall turnaround time with no messages aggregation which is due to the latency of composite messages creation
- But WHY no improvement with so much less messages to deal with on the controller side?
- The reason is because the actual processing of composite messages takes place by treating each EPILOG complete message one by one so `_slurm_rpc_epilog_complete` **is still executed n times.**
- Hence we need to create a new function for the processing of composite messages in order to treat the epilog messages as an array and gain the time of locks, node_state_save,etc.

Conclusion and Future Works

- Re-factoring of forwarding logic in SLURM to consider the network topology design
  - Improves internal communications in general due to a better mapping of SLURM communication trees upon the underlying physical network
- Implementation of messages aggregation for reverse tree communications
  - Reduces the number of incoming TCP connections to serve on the controller
  - Still need to optimize the processing of those RPC messages in groups.
  - The logic of messages aggregation should be extended to be used for all types of messages (squeue, sinfo demands, node registration messages, etc)

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