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AWERBUCH'S SYNCHRONIZERS (ALPHA, BETA, GAMMA)

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The problem

Synchronization

Synchronization in distributed systems is crucial for maintaining coherence and ensuring consistent behavior across processes, especially in transitioning from synchronous to asynchronous environments.

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What is the solution/contribution

- Implementation of Alpha, Beta, Gamma Algorithms on the AHCv2 platform.
- Anlysis of the algorithms within different topologies

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Motivation/Importance-1

These synchronizers play a pivotal role in distributed systems by enabling coordination and consistency among processes operating in asynchronous environments. Their importance lies in their ability to bridge the gap between synchronous and asynchronous systems, allowing distributed applications to maintain coherence and achieve desired outcomes despite the lack of a global clock or fixed time intervals.

Motivation/Importance-2

Without effective synchronizers, distributed systems would struggle
to ensure consistent behavior, leading to potential issues such as data
inconsistencies, race conditions, and overall system instability.
Therefore, these synchronizers serve as fundamental building blocks
for the reliable and efficient operation of distributed systems in
various domains, including cloud computing, networking, and parallel
computing.

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Model, Definitions

- Synchronization: The process of coordinating actions or events across distributed entities to maintain coherence and consistency.
- Asynchronous Systems: Distributed systems where processes operate independently without a global clock or fixed time intervals.

Background and this slide can be combined....

Background

The 1985 paper Awerbuch "Complexity of network synchronization" proposes the method for alpha beta gamma synchronizers(without naming them as alpha beta gamma) and analyzes the trade-offs between them in this paper. So in essence its a paper that introduces simple methodologies for designing efficient distributed algorithms in asynchronous networks.

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Alpha

- In the alpha synchronizer, every node sends a message to every neighbor in every round(so that neighboor can synchronize with it)
  - If no message needs to be sent to that neighboor, node sends a dummy message to that neighboor.
- The receiver waits until it receives a message from every neighbor for a particular round before proceeding to the next round.

Alpha Algorithm

Listing 1: Awerbuch's alpha algorithm.

```
1  Implements:
2  Uses:
3      set_neighbors_not_received,  # sets every value in adjnd as not received or False
4      create_current_round_messages,  # creates messages for current round
5      do_round_process,
6      set_received_rmd_messages_to_none,
7      send_messages_to_neighbors,
8      set_timer,  # set timer that after given time calls the given function with given
    parameters. repeats itself until reset_timer call
9      reset_timer,
10 Events:
11     Init,
12     NewRoundEvent,
13     OnMessageReceive,
14 Needs:
15     adjacent_nodes_dict: adjnd
16     received_messages_dict: rmd  # for storing this round's messages
17
18 OnInit: () do
19     round = 0
20     NewRoundEvent()
21
22 NewRoundEvent () do
23     round += 1
24     unreceived_count = len(adjnd)
25     set_neighbors_not_received()
26     do_round_process()  # doing the algorithm event since it received every needed mesage
27     set_received_rmd_messages_to_none()
28     current_round_messages = create_current_round_messages()
29     send_messages_to_neighbors(round, current_round_messages)
30     set_timer(send_messages_to_neighbors, round, current_round_messages)
31
32 OnMessageReceive: ( neighbour_round, neighbour_node, message ) do
33     If neighbour_round == round and adjnd[neighbour_node] == False:
34         adjnd[neighbour_node] = true
35         unreceived_count -= 1
36         rmd[neighbour_node] = message
37         If unreceived_count == 6:
38             reset_timer()
39             NewRoundEvent()
```

Beta

- In the beta synchronizer, messages sent by processes are acknowledged by their receivers.
- Senders wait until they receive acknowledgments (ACKs) from all receivers for the messages they sent in a particular round.
  - That is why since its a reliable connection we act like receive happens only ones(think of TCP)
- Once all ACKs are received and all OKs from child nodes are received, the node sends ok to parent node.
- Once root receives OK from its parent nodes it broadcasts GO signifying the start of new round

Beta Algorithm

Listing 2: Awerbuch's Beta algorithm.

```
1  Implements:
2  Uses:
3      create_current_round_messages,  # creates messages for current round
4      do_round_process,
5      set_received_rmd_messages_to_none,
6      send_messages_to_neighbours,
7      is_root,
8      broadcast_go,
9  Events:
10     Init,
11     NewRoundEvent,
12     OnMessageReceive,
13     OnOKReceive,
14     NodeRoundEndCheck,
15 Needs:
16     parent_node,           # if parent node is none it is root
17     adjacent_node_count: adj_count,
18     children_node_count: child_count,
19     received_messages_dict: rmd  # for storing this round's messages
20
21 OnInit: () do
22     NewRoundEvent()
23
24 NewRoundEvent () do
25     unreceived_count = adj_count
26     unreceived_OK_count = child_count
27     do_round_process()  # doing the algorithm event since it received every needed mesage
28     set_received_rmd_messages_to_none()
29     current_round_messages = create_current_round_messages()
30     send_messages_to_neighbours(round, current_round_messages)
31
32 OnMessageReceive: ( neighbour_node, message ) do
33     unreceived_count -= 1
34     rmd[neighbour_node] = message
35     NodeRoundEndCheck()
36
37 OnOKReceive: ( child_node ) do
38     unreceived_OK_count -= 1
39     NodeRoundEndCheck()
40
41 NodeRoundEndCheck: () do
42     If unreceived_count == 0 and unreceived_OK_count == 0:
43         If is_root():
44             broadcast_go()  # every node will activate newroundevent when they receive it
45             NewRoundEvent()
46         Else:
47             SendOK(parent_node)
```

Figure:

Gamma

- The gamma synchronizer is the merge of both alpha and beta synchronizers. It does this by having multiple roots which all have their own spanning trees where:
  - The beta algorithm runs within each tree
  - The alpha algorithm runs between trees
- In here in addition to beta when the root of a tree gets all acks and OKs, it sends ready to the roots of all adjacent trees (and itself).
  - Two trees are considered to be adjacent when any of their members are adjacent.
- When the root is READY(which means every one of its descendants are OK). And all their adjacent nodes are READY(which it knows by receiving their message). It broadcasts go down its tree

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Main Result Alpha

Alpha: guarantees local synchronization, ensuring that no process proceeds to the next round since it waits for all its neighbors which means it knows every neighboor finished its previous message neighbors have completed the current round.

Main Result Beta

guarantees global synchronization, ensuring that no process proceeds to the next round since everyone waits for root and root waits for OKs from its children And since its children being OK would recursively prove that every other node is OK this algorithm is correct.

Main Result Gamma-1

As in the alpha synchronizer, we can show that no root process to the next round unless it and all its neighbors are in ready state, which happens only after both all nodes in the root's tree and all their neighbors have received acks for all messages. This proves that within nodes there is local syncronization.

Main Result Gamma-2

And since every tree uses beta syncronizer in itself we can see that within that tree networkwise syncronization has been achieved.

Main Result Gamma-3

Since every connection of a node inside 1 tree to another implies connection between roots the syncronization of roots will be achieved. While this sentence does not prove its correctnes, the idea of thinking every tree as a giant node will since it will make the situation same as a normal alpha synchronizer.

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Conclusions

- Awerbuch's Alpha, Beta, and Gamma synchronizers provide mechanisms for coordinating processes in asynchronous distributed systems.
- Alpha guarantees local synchronization, ensuring processes wait for neighbors to finish a round before proceeding.
- Beta achieves global synchronization, with all processes waiting for a "GO" signal from the root after it receives acknowledgements from all children.
- Gamma combines Alpha and Beta, using Beta within trees and Alpha between trees, achieving both local and global synchronization.

References

- Awerbuch, Baruch. "Complexity of network synchronization." Journal of the ACM (JACM) 32.4 (1985): 804-823.

Questions

THANK YOU

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