A Defect Tolerance Mechanism for Mobile Nano-machine Networks

Sema Oktug and Birkan Polatoglu

Computer Networks Research Lab

Istanbul Technical University

Agenda

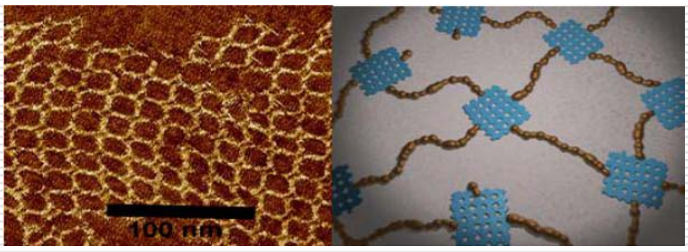
- Previous Work: Defect Tolerance Techniques for DNA Self-Assembly
- Proposed Defect Tolerance Mechanism
- Example Scenairos
- Conclusion

Defect Tolerance Techniques for DNA Self-Assembly

1. Defect Tolerance Technique using Reverse Path Forwarding
   - **Patwardhan, J. P., Dwyer, C., Lebeck, A. R., and Sorin, D. J.,** 2005: Evaluating the connectivity of self-assembled networks of nano-scale processing elements.
2. Defect Tolerance Technique using Combined Wave Expansion Reverse Path Forwarding
   - **Demoracski, L. and Lombardi, F.,** 2006: Connecting and Configuring Defective Nano-Scale Networks for DNA Self-Assembly.

Patwardhan, J. P., Dwyer, C., Lebeck, A. R., and Sorin, D. J., 2005: Evaluating the connectivity of self-assembled networks of nano-scale processing elements.

- DNA Self-Assembly
  - Bottom-up fabrication technique
- Self-assembled DNA lattice act as a base



Atomic force microscope image of DNA lattice [1]

Schematic of self-assembled network of nodes [1]

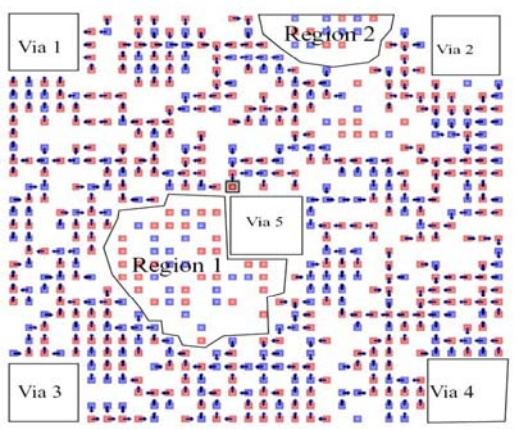
DNA Self-Assembly

+ Well suited to assemble large numbers of dense circuits.
– Prone to higher defect rates
  – No control over placement
  – Requires effective defect tolerance technique
- Defective node
  - Can not perform any processing or communication

Defect Tolerance Technique using Reverse Path Forwarding [1]

- Map out defective nodes at startup
  - Reverse Path Forwarding
- Broadcast tree of non-defective nodes
- Does not require an external defect map
- Each node have four transceivers
- Fail-stop defect model

Defect Tolerance Technique using Reverse Path Forwarding



System Architecture [1]

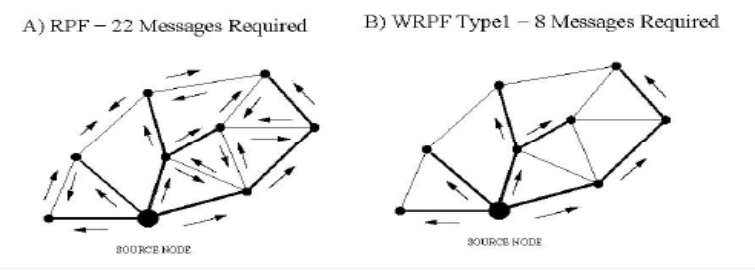
Defect Tolerance Technique using Combined Wave Expansion RPF

- Three algorithmic improvements over RPF.
  1. 1-hop wave expansion
  2. Divide and conquer approach
  3. Unsafe node notion

[2] **Demoracski, L. and Lombardi, F.,** 2006: Connecting and Configuring Defective Nano-Scale Networks for DNA Self-Assembly. Nano-Net

1-hop wave expansion

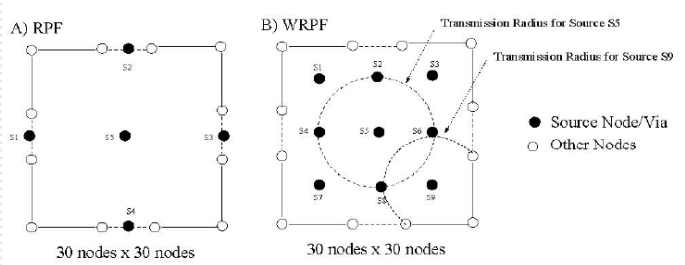
- Exchange information with 1 hop neighbors.
- Message passing reduced.



Message Passing Comparison [2]

Divide and conquer approach

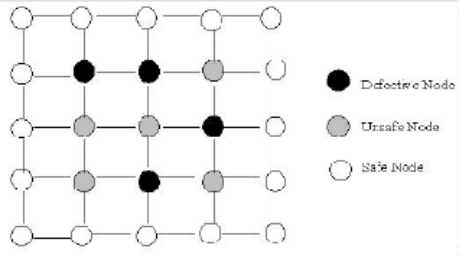
- Number of vias increased and better organized
- Independent trees of each via



Via Placement Comparison [2]

Unsafe node notion

- The node is considered as unsafe if;
  - Neighbour to two or more unsafe or defective nodes.



Unsafe and Defective Nodes [2]

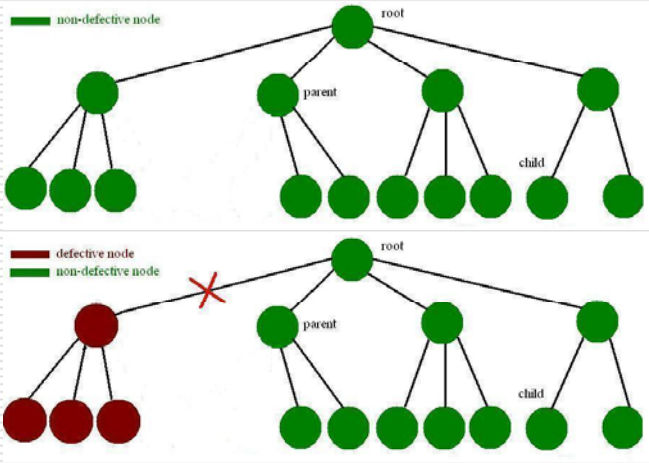
Agenda

- Previous Work: Defect Tolerance Techniques for DNA Self-Assembly
- **Proposed Defect Tolerance Mechanism**
- Example Scenairos
- Conclusion

Motivation

- Previous works focus on the systems containing stationary nano-machines.
  - Aqueous medium
- Broadcast tree at startup
- Transient and permanent faults

Broadcast Tree After Link Failure

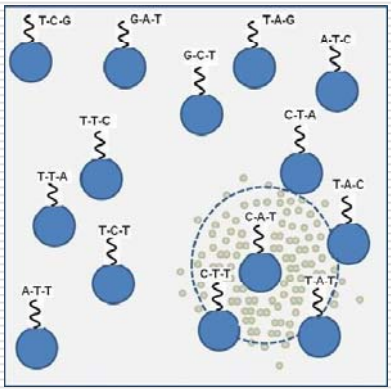


Proposed Mechanism

- Each node in the system is considered as cell.
  - Relax the number of neighbours
- Culture environment in [3].
- Network of mobile nano-machines
  - Molecular communication
- "Node division" notion
- "Free non-defective" state

[3] **Çakır, A. R. and Oktuğ, S. F.,** 2010: Nanonetwork Messaging Techniques and Database Implementations Using Humoral Immunity, *MSc Thesis (Work also Submitted to the Nano Communication Netwoks Journal).*

System Architecture



System Architecture

- Nanomachines
  - Randomly scattered
  - Floating on the aqueous medium.
- Convenient environmental conditions
  - Temperature
  - Humidity
  - pH

Nodes (Cells)

- States
  - Defective
  - Non-defective
  - ***Free non-defective***
- Identified with ssDNA with the purpose of unique adressing [3]
- Communication radius

Nodes (Cont'd)

- Simple database [3]
  - The addresses (ssDNAs) of the nodes in its communication range.
  - The special broadcast packet
- Divided and corrupted in their lifecycles
- Via; external interface

Proposed Defect Tolerance Mechanism

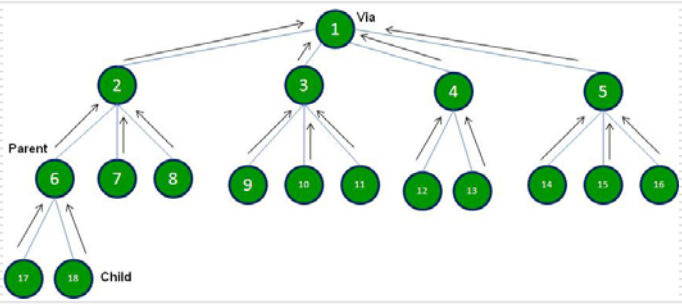
- When a node gets the special broadcast packet;
  1. Checks if this packet is forwarded previously or not.

     YES
     1. Does not forward the packet.

     NO
     1. Stores the broadcast packet in its database.
     2. Releases the broadcast packet to the medium.

Proposed Defect Tolerance Mechanism (Cont'd)

- Tree-like graph structure
  - Rooted at via
- The next step to reach the via.



Failure Scenarios

1. Corruption of the non-defective node
   - Node failure
2. Node's walk away from its parent's communication range.
   - Link failure

Free non-defective notion

- The children or the nodes in the sub tree under failed node
- Nodes that do not take packet from parent during specific timeout interval
- Disconnected from their parents

Parent Search (PS) Algorithm

- Free non-defective node searches for a new parent
  - Release trigger message
  - The non-defective node in communication range
    - Sent packet containing its address
  - Each child run PS algorithm recursively

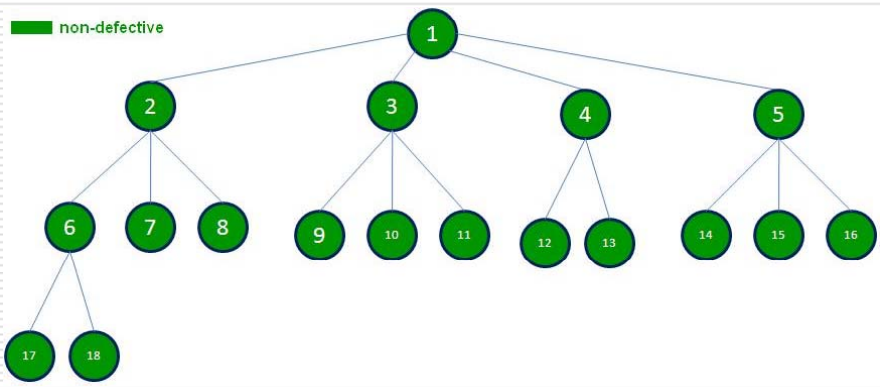
Agenda

- Previous Work: Defect Tolerance Techniques for DNA Self-Assembly
- Proposed Defect Tolerance Mechanism
- **Example Scenairos**
- Conclusion

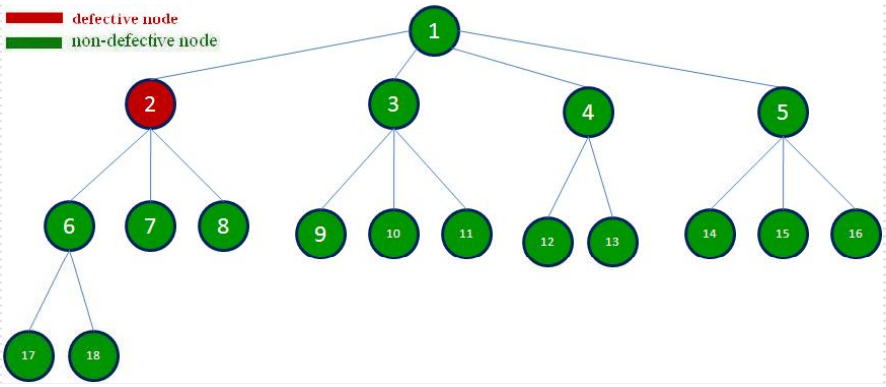
Example Scenairos

1. Node Failure
   - Cell Death
2. Link Failure
   - Node walk away from its parent communication range
3. Node Division
   - Cell Division

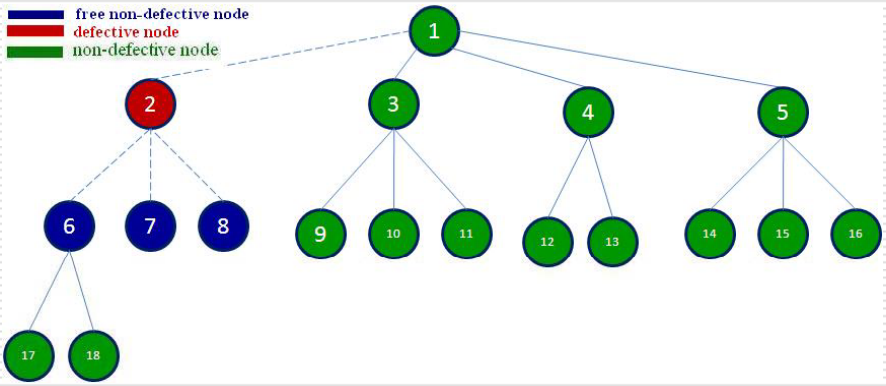
Tree-like graph at startup



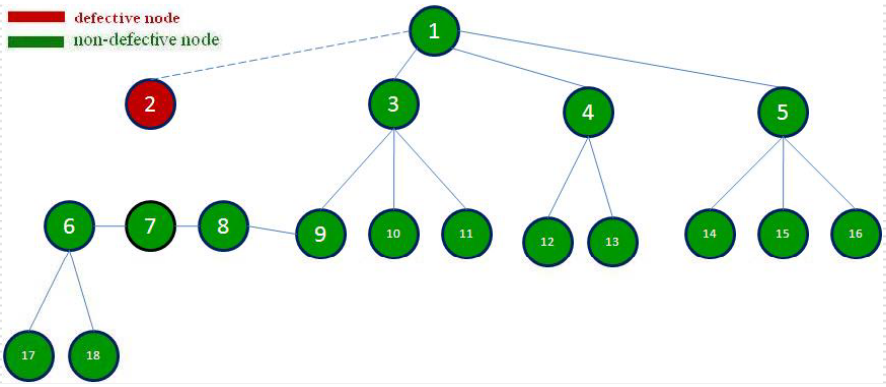
Node Failure



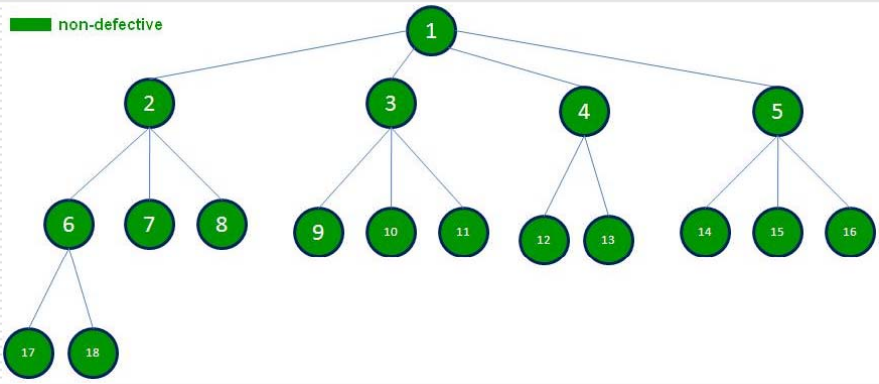
Node Failure (Cont'd)



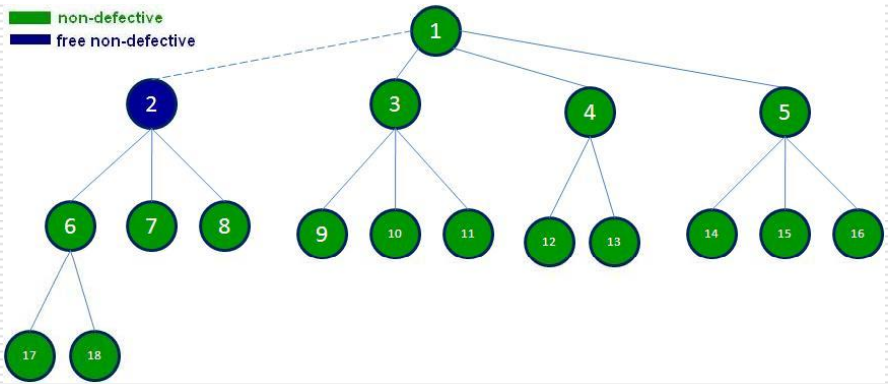
Node Failure (Cont'd)



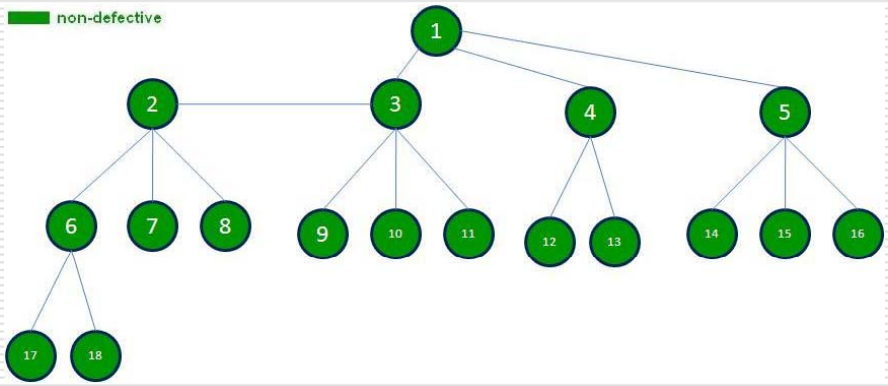
Tree-like graph at startup



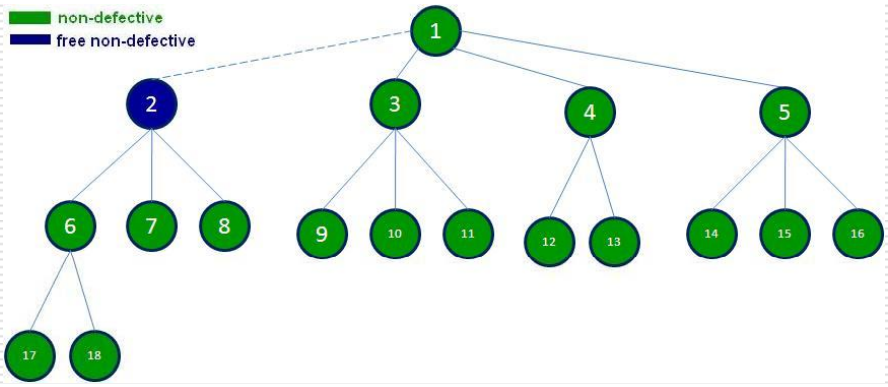
Link Failure



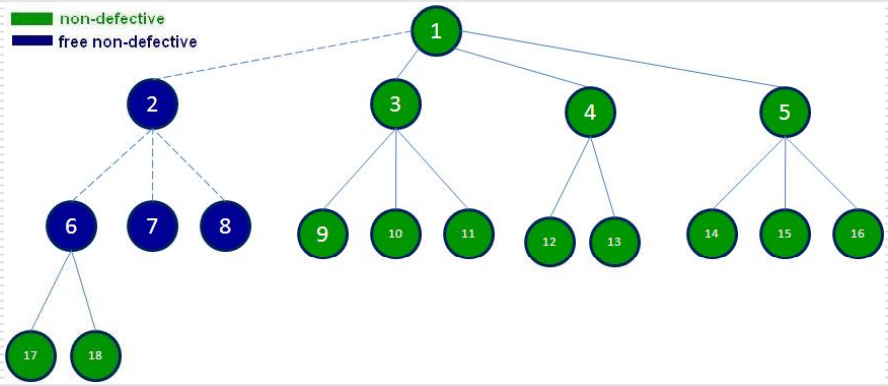
Best Case



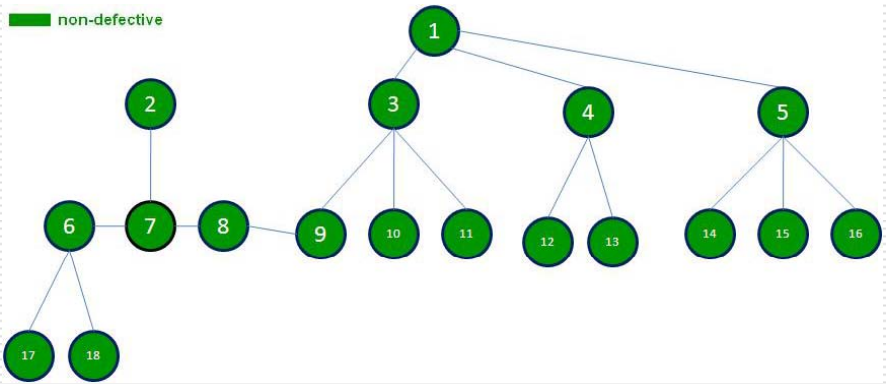
Link Failure



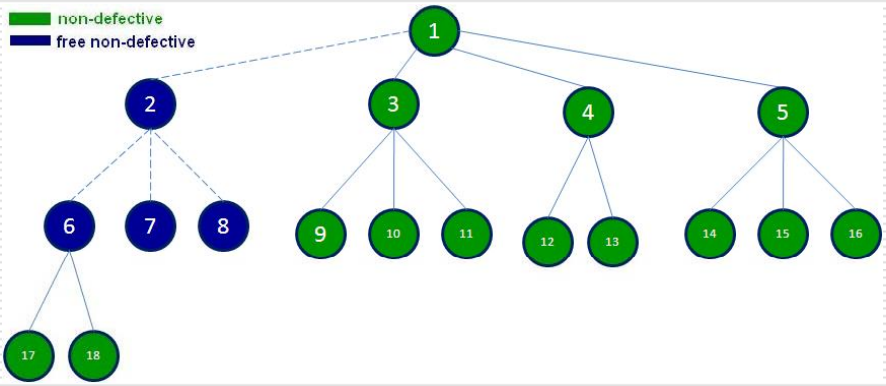
No Parent Found



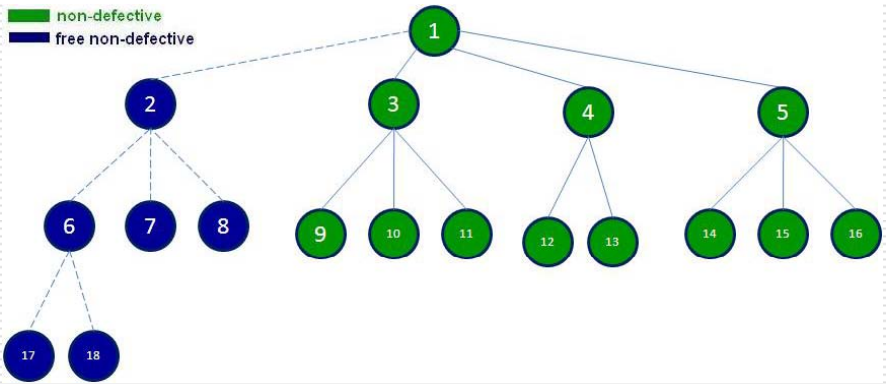
Worse Case



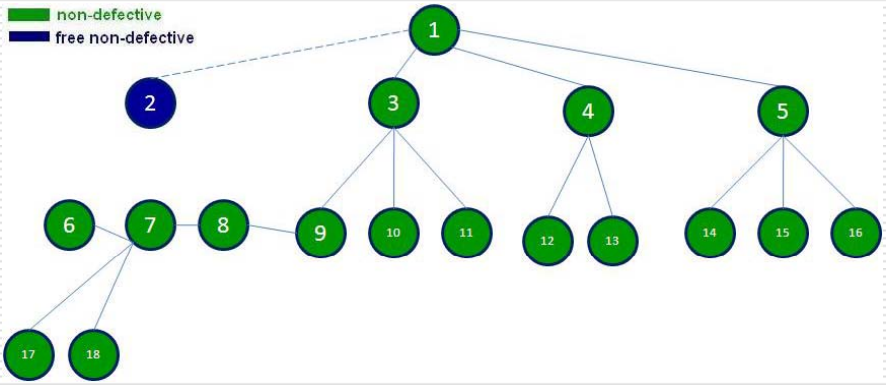
No Parent Found



No Parent Found



Worst Case

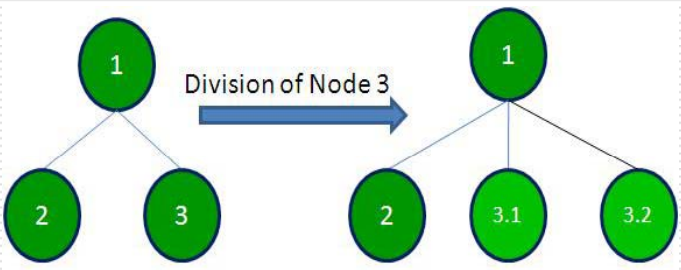


Node Division

- Cell division in cell culture
  - Two daughter cells originated with the same characteristics
- Nano nodes in the system are inspired from biological cells
  - Nodes are divided in their lifecycle [3].
- The addresses of the daughter nodes of *"1"* will be *"1.1"* and *"1.2"*.

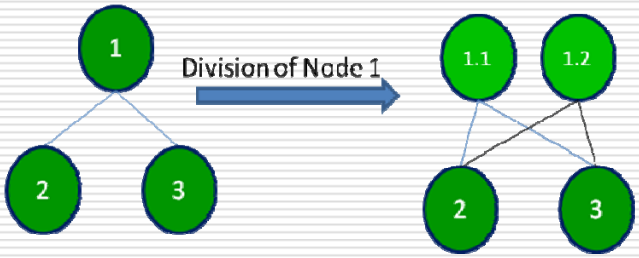
Child Node Division

- Daughter node knows the address of its parent

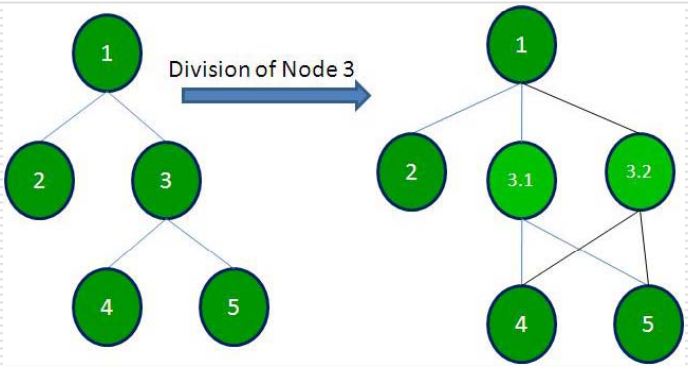


Parent Node Division

- Changes the broadcast tree structure
- Tree-liked graph structure.



Parent Child Node Division



Agenda

- Communication Among Nano-machines
- How to bring Nano-machines together
- Defect Tolerance Techniques for DNA Self-Assembly
- Proposed Defect Tolerance Mechanism
- Example Scenairos
- **Conclusion**

Conclusion

- A defect tolerance technique proposed for networks of mobile nano-machines.
  - Cell based environment
- Tree-like graph structure observed
- Handles following scenarios:
  - Node corruption
  - Disconnection of node with its parent
  - Node division

Conclusion (Cont'd)

- Tree-like graph structure
  - Alternative paths from one node to via
  - More robust
- Further researches will be focused on:
  - Trigger mechanism to find out new parent
  - Timeout mechanism of free non-defective nodes.

Questions?

- Thanks...

Sema Oktug: oktug@itu.edu.tr

- **Polatoğlu, B. and Oktuğ, S. F.,** 2010: A Defect Tolerance Mechanism for Self-Assembled Networks of Mobile Nano-Machines, The 6th Nanoscience and Nanotechnology Conference (NanoTR6), Izmir, June 15-18.

NanoNetworking Group at Istanbul Technical University

Prof. Sema Oktug, Dept. of Computer Engineering
Assoc.Prof. Fatma Nese Kok, Dept. of Molecular Biology
Assoc.Prof. Günes Kurt, Dept. of Electronics-Comm. Engineering
Students: Hakan Tezcan (Phd), Alper Cakir (MS), Birkan Polatoglu (MS)