Self-Deployment, Self-Configuration: Critical Future Paradigms for Wireless Access Networks

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Outline

- Background: Emerging trends for wireless access networks
- Overview: Current hierarchical network architecture with centralised control.
- Future distributed architecture: flexible, self-deploying, self-configuring, and self-healing.
- Approach: Exploit basic sciences of complexity.
- Example: self-configuration using cellular automata concepts.
- Conclusions

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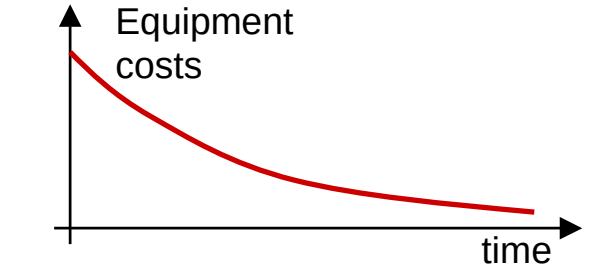
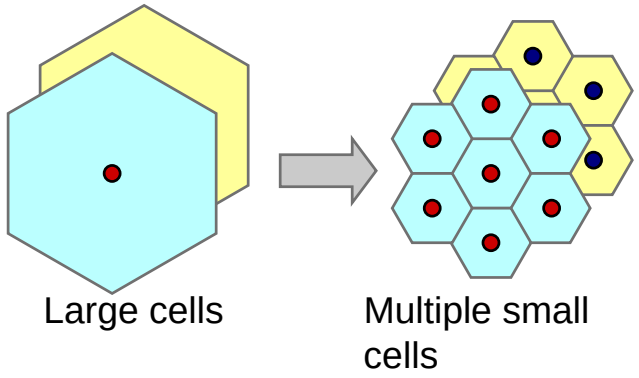
Background

Emerging trends for wireless access networks:

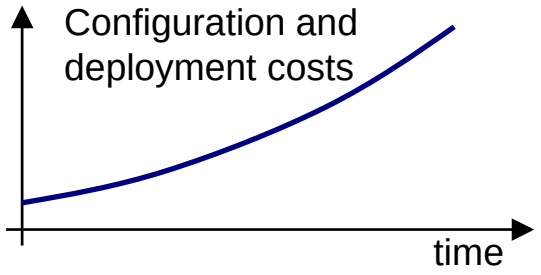
- Reduction in equipment costs.
- Reduction in cell size to increase capacity. This is accompanied with an increase of the total number of cells.
- Additional complexity as interoperability between heterogeneous systems (e.g. different access technologies) becomes economically critical.





Implications:

- Increase of the relative costs for deployment and configuration.
- Self-configuration helps to control the costs.
- Strong need for additional novel concept of self-deploying network.



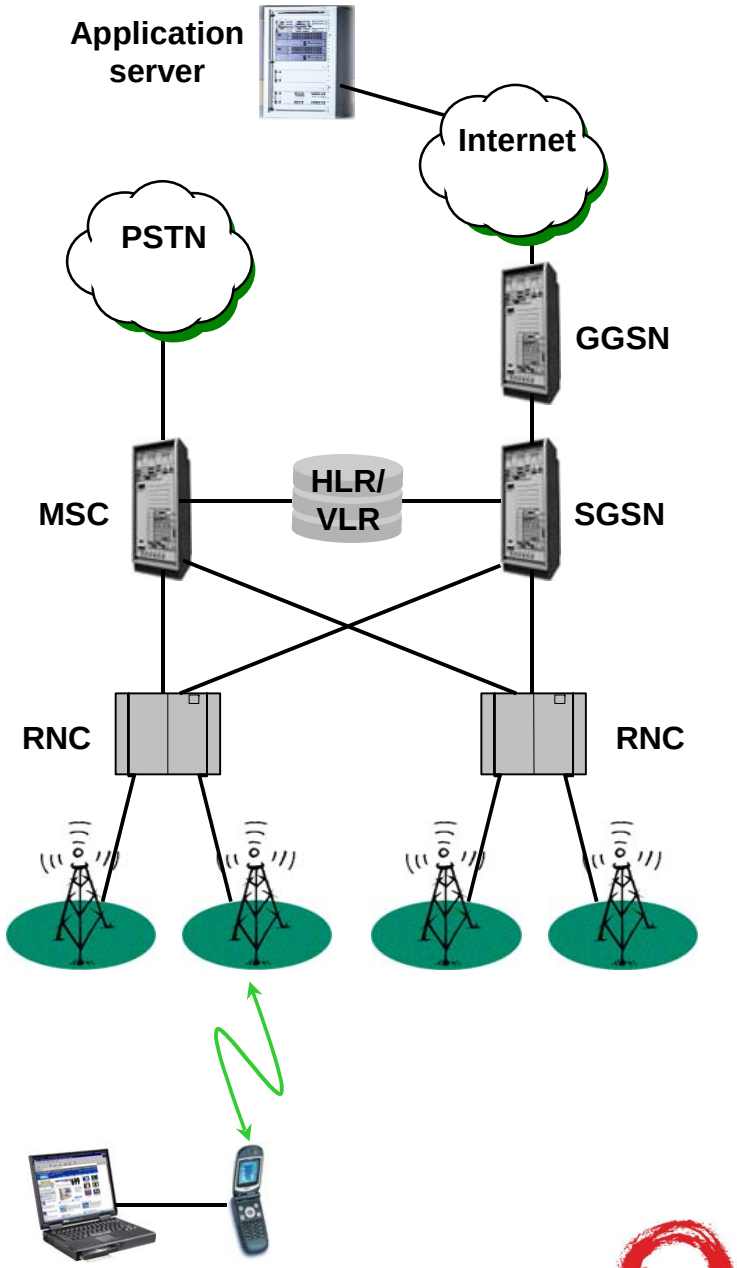
Current architecture

Characteristics:

- Extremely centralised control.
- Hierarchical in terms of architecture.
- Isolated with respect to other systems.
- Very inflexible as far as adapting to new services and traffic demands.

Future development:

- Communication systems will become richer in features and capability.
- Isolation between systems will have to decrease.



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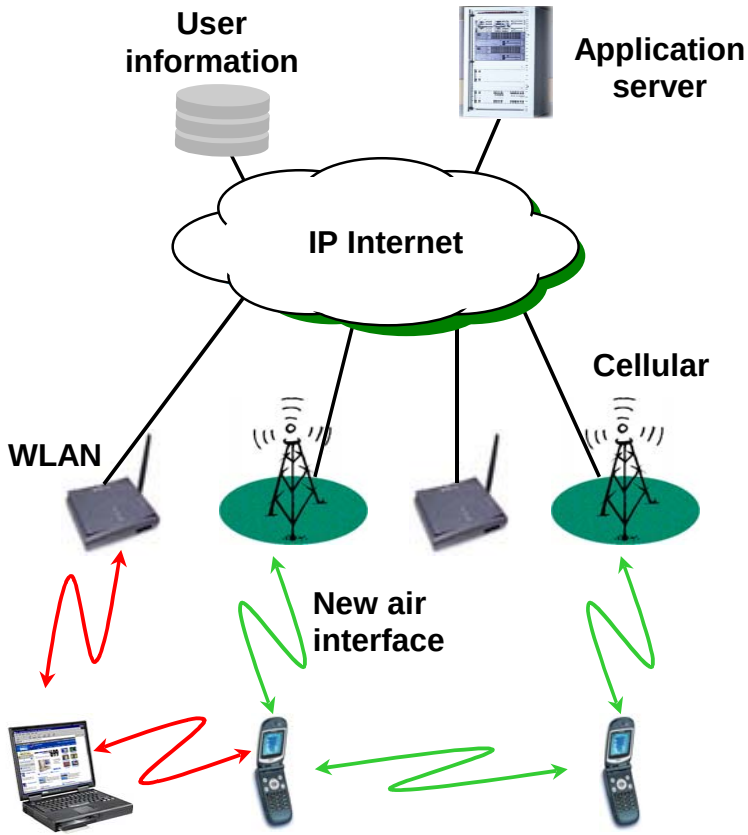
Future distributed architecture

Characteristics:

- Distributed control.
- Simple, flat architecture.
- Highly integrated with other systems.
- Flexible to keep up with changes in user needs and terminal capabilities.
- Owned by several entities

Requirements:

- High robustness of ad-hoc, dynamic architectures both technically and economically.
- Self-deploying and self-healing with nodes that are auto-configurable and flexible.



Self-deployment: a critical future requirement

Current manual deployment of a new cell:

- Manual site selection and deployment.
- Drive testing of coverage.
- Manual adjustments and configuration of new and neighbouring cells.
- Drive testing to verify configuration.

Future self-deployment:

- The network identifies autonomously the need for a new base station.
- The network calculates the optimum position.
- Auto-configuration of new and all affected base stations in the network.

Characteristics:

- The network makes the decisions on positioning autonomously.
- No manual site selection, configuration and measurements necessary.

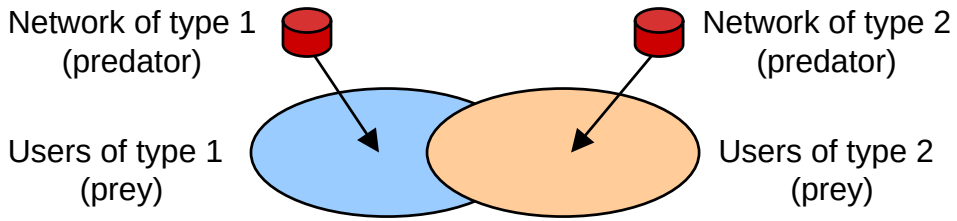
Approach (1/3)

- Exploit basic sciences of complexity with a heavy emphasis on novel synthesis methods, beyond current analytical techniques.

Promising candidates:

- **Spatiotemporal models of population growth**
  - Deployment of wireless network in presence of competition is directly analogous to the population growth of a species competing with others for limited resources.
  - Mathematical models of ecology should have relevance for the prediction of network growth.
  - Niche theory with its concepts of overlapping niches can be used as framework for analysing the impact of competition.

Example:



Approach (2/3)

Promising candidates (contd.):

- **Swarm Intelligence**
  - Biological swarms (e.g. ant colonies) are a good example of self-organised systems based on distributed processing.
  - Mechanisms can provide useful templates for wireless networks.

  Example: principle of stigmergy

  > Modifications of the environment of one member of the swarm result in changes of the behaviour of other members.

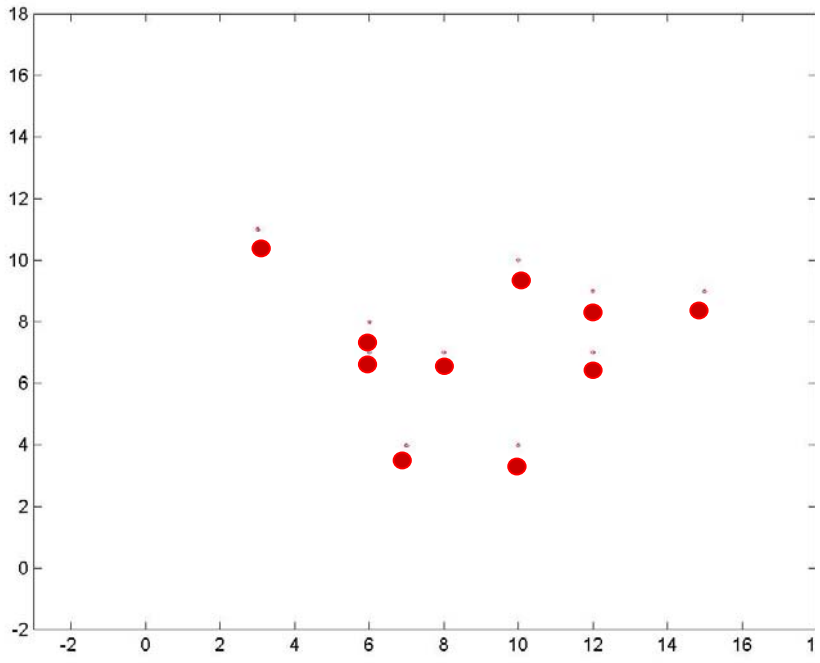
- **Microeconomics of oligopolies and game theory**
  - One of the best known paradigms for the design of distributed systems competing for resources.
  - Recognised optimisation properties of free market scenarios.
  - Use concept of an abstract “market price” for given resources. Further work is needed to take account of actual economic drivers.
  - Possibility to optimise for maximum revenue.

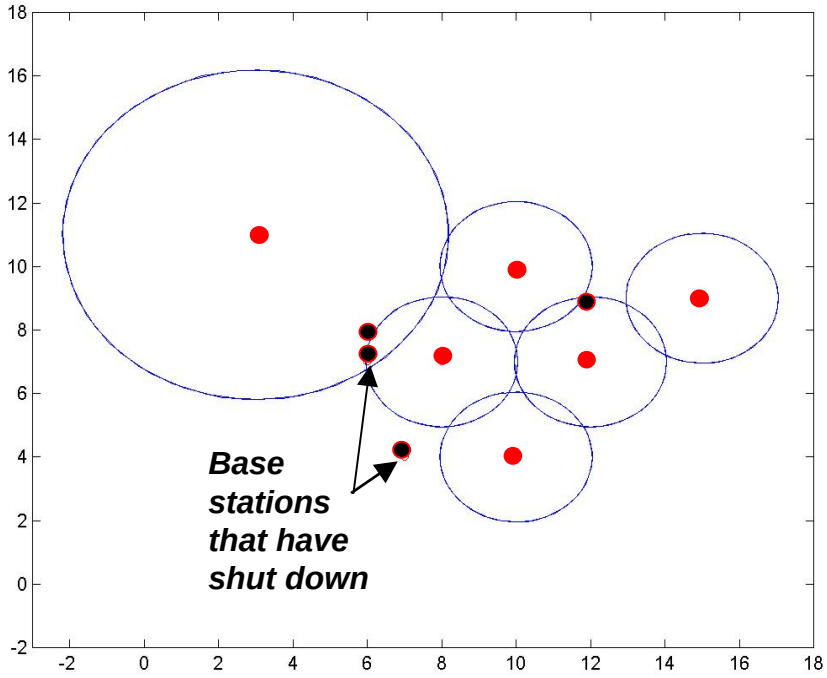
Approach (3/3)

Promising candidates (contd.):

- **Entropy-based complexity measures**
  - To characterise behaviour and performance in complex systems.
  - Detect and avoid points of instability in complex systems.
- **Cellular automata (CA)**
  - CA represent a collection of simplistic locally interacting nodes, which can provide sophisticated global behaviour .
  - A self-organising network has characteristics similar to CA when simple algorithms are used.
  - Due to limited local information, simple algorithms can provide similarly good results as complex algorithms from modern control theory.
  - The distributed and global behaviour has the robustness and scalability which is difficult to achieve in centralised approaches.

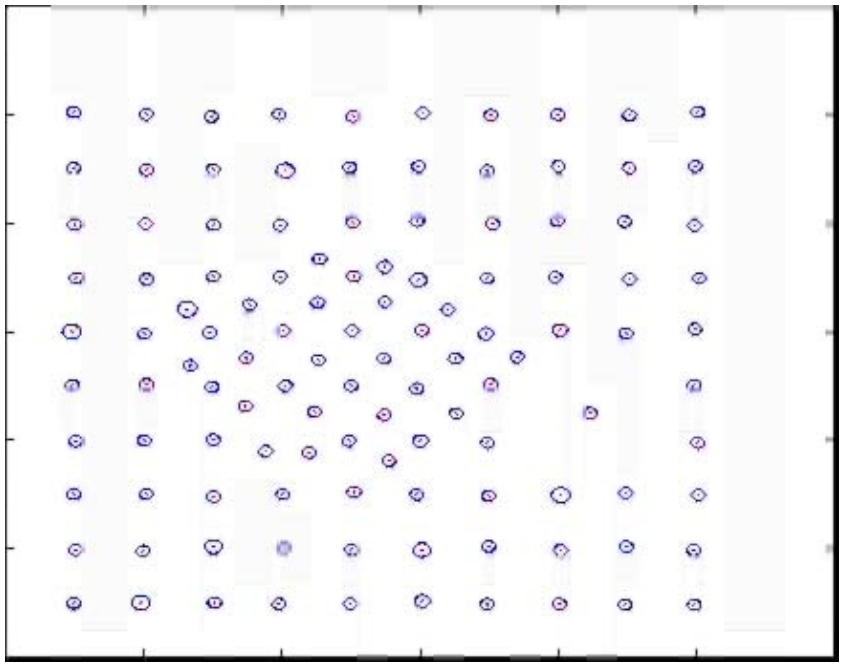
Example of an Application of Cellular Automata

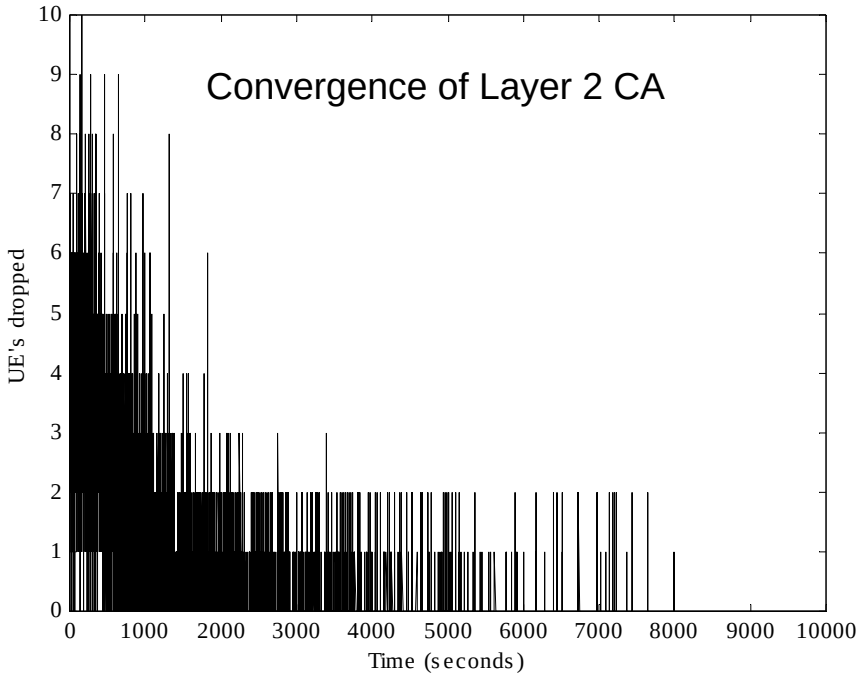




- Network viewed as *cellular automata (CA)* and each base station is configured based on local rules with nearest neighbors.
- Auto-configuration sets power levels to achieve maximum coverage.
- In this example, some base stations shut-down.

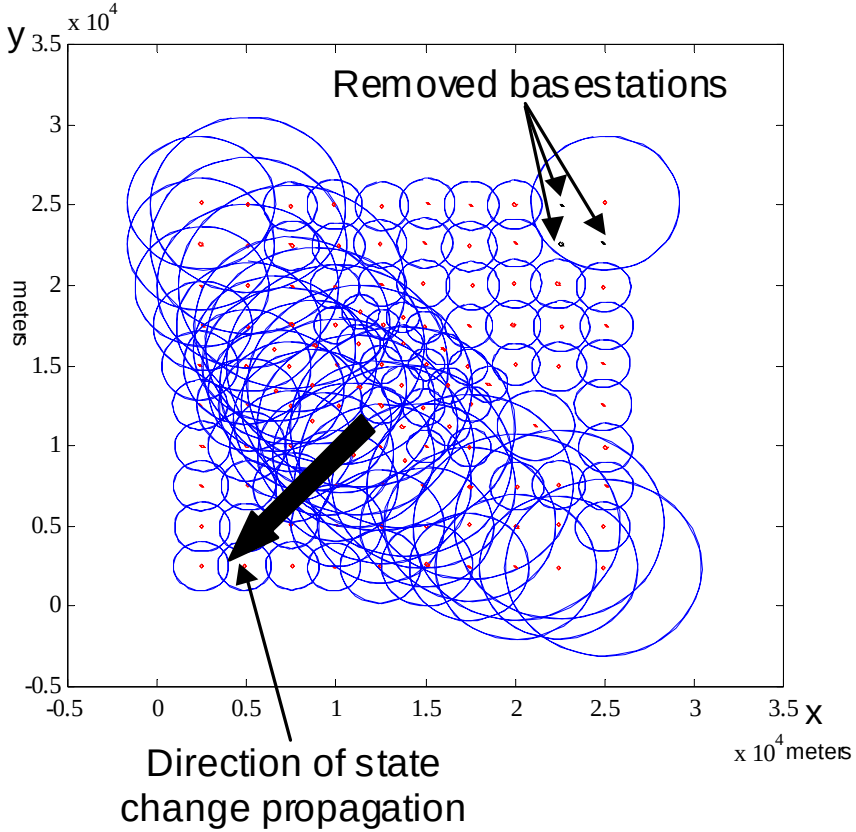
Video Showing Auto-Configuration using Cellular Automata Concepts

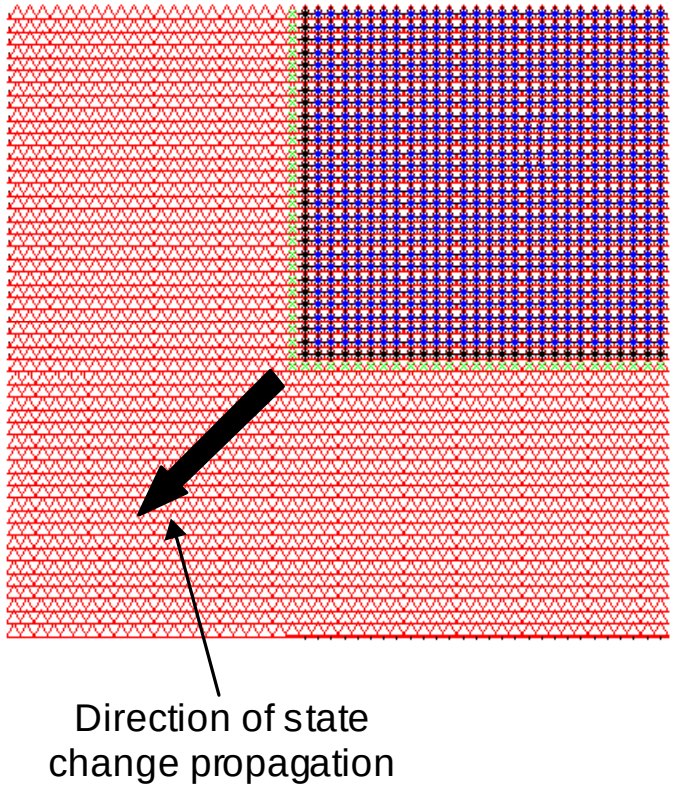




- Two phases of optimisation:
  - Layer 1 CA with just inter-base station interactions.
  - Layer 2 CA with additional interactions with mobile terminals.

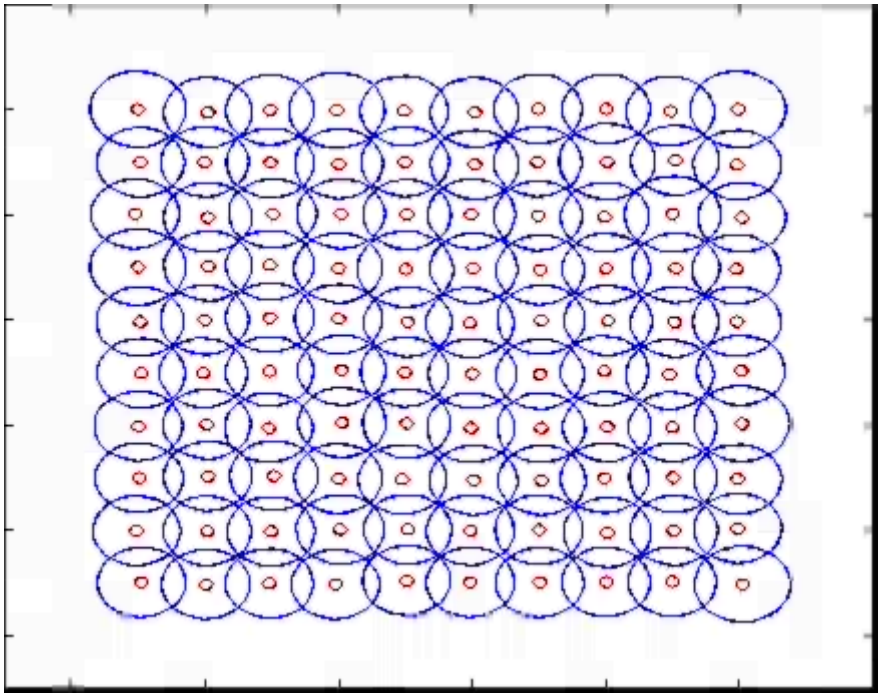
Example of reaction to failed base stations using Cellular Automata Concepts





- The failure of base stations triggers a re-configuration process for the neighbouring base stations.

Video of reaction to failed base stations using Cellular Automata Concepts



- The re-configuring process updates the configuration of the whole network (shown for a 1 Layer CA).

Conclusions

Benefits:

- Distributed algorithms can potentially improve the robustness and availability.
- Possibility of high integration with other access technologies.
- High flexibility to keep up with changes in user needs and terminal capabilities.
- Fast system deployment for emergency systems.
- Reductions in operators' opex.

  (Capex is decreasing and cell size is reducing
  $\Rightarrow$ deployment and configuration will dominate costs)
- Coupling a well-defined application (deployment of radio networks) to the basic sciences of complexity will result in significant advances in the latter.

Risks:

- New techniques could fail to achieve financial robustness.