Combinatorial Epidemiology

Perfect Information. Optimal Safety

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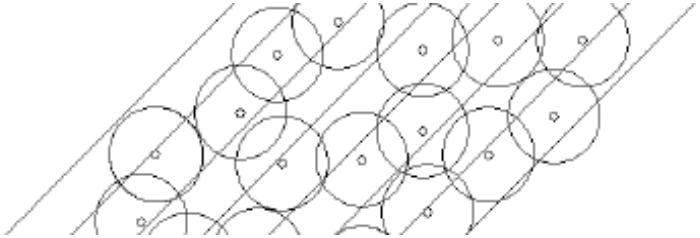
Very brief:

Spread due to Proximity

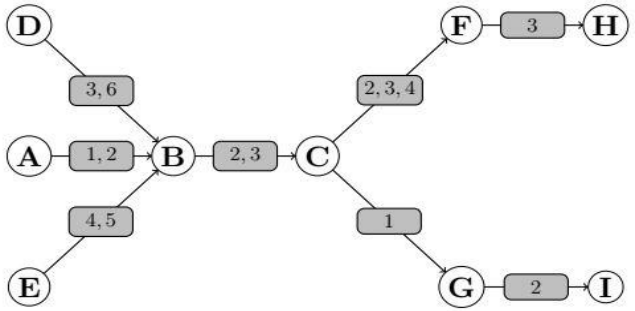


In-depth:

Spread due to Movement

Patient-zero

Forward detection

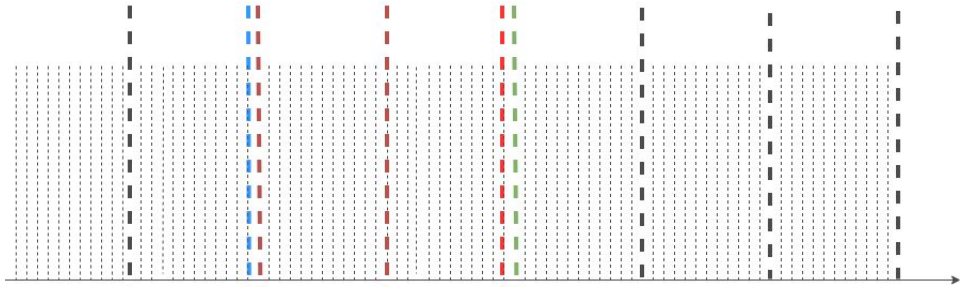


Highly In-depth:

Relationship between

Time of Movement, and

Time of Detection



Proximity spread

Proximity Spread is described by a Unit-disk graph,

Immunization can be done on a Vertex Cover, or any structure describing Centrality.

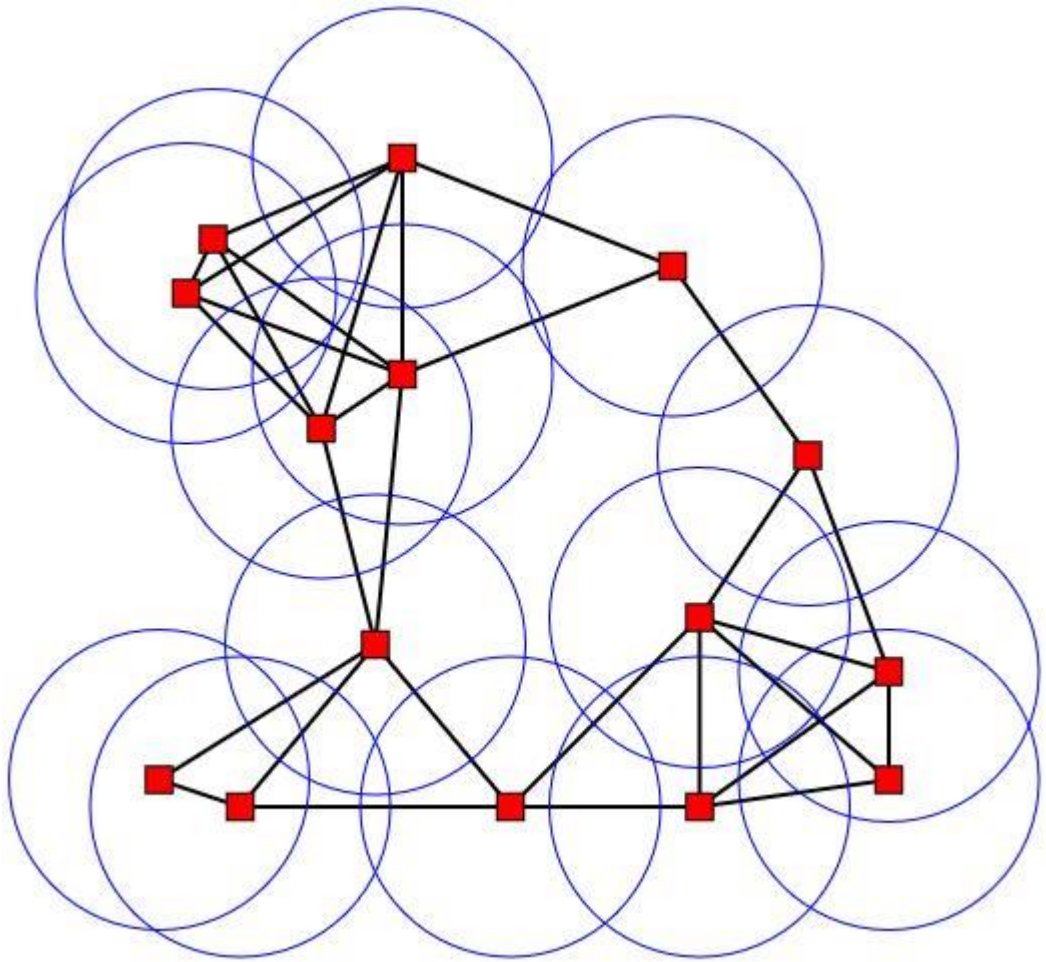
Good opportunity to apply optimization techniques to approximate Vertex Cover.

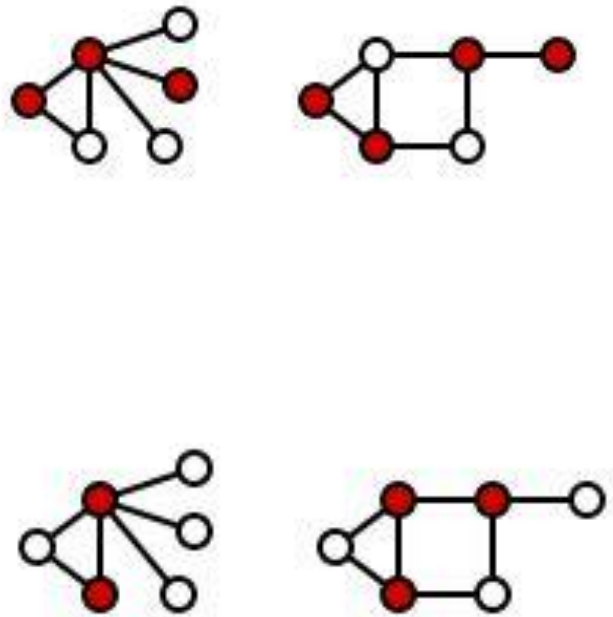
Immunization of the Vertex Cover ensures no illness spread is present due to Proximity.

More formally, a Unit Disk Graph is a structure

$U = (L, r)$ for $L \subseteq \mathbb{N} \times \mathbb{N}$ and a real value r serving as radius for the disk

Proximity spread





Statistics

110,000 farms
2,658,619 distinct moves
3,336,089 non-distinct moves

72,200 sending farms
52,685 receiving farms

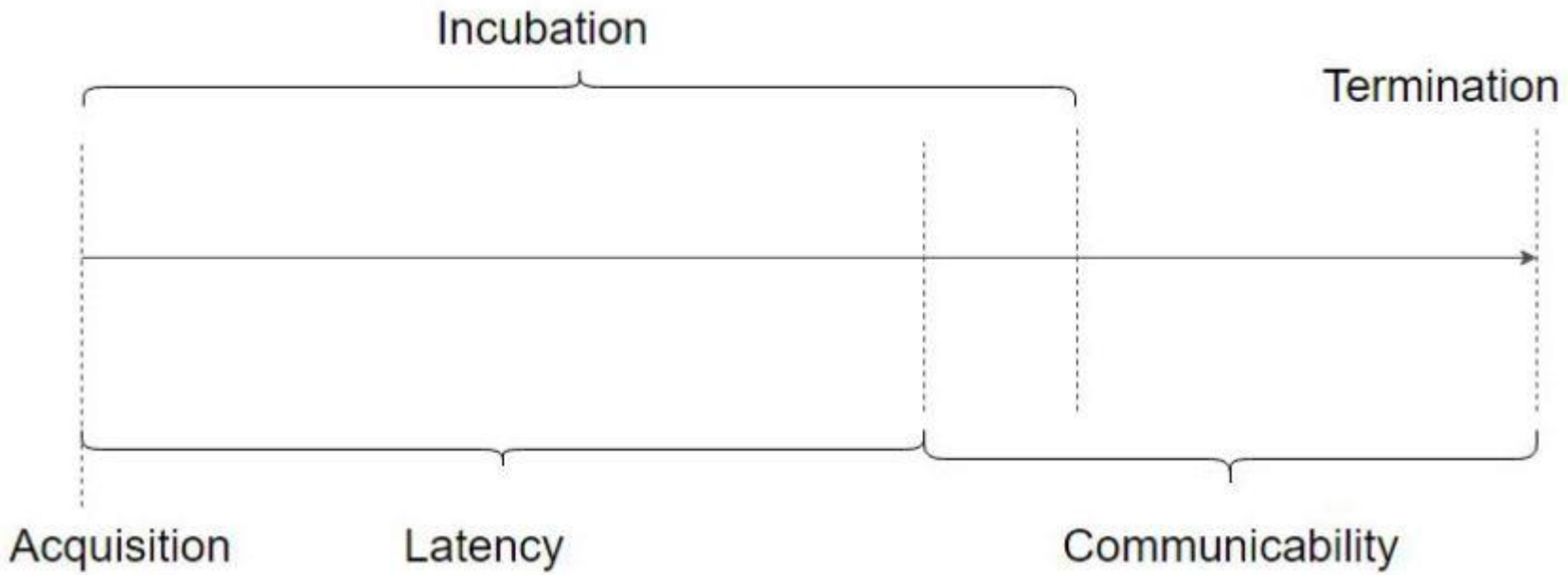
82,127 distinct senders and receivers

9,115 components on receiving farms
19,814 components on the sending farms

A mix of SQL queries and hardcoded Java procedures was used.

Animal movements can be seen as a temporal graph, in which temporal paths are paths through the underlying graph that respect the natural order of time.

An assumption

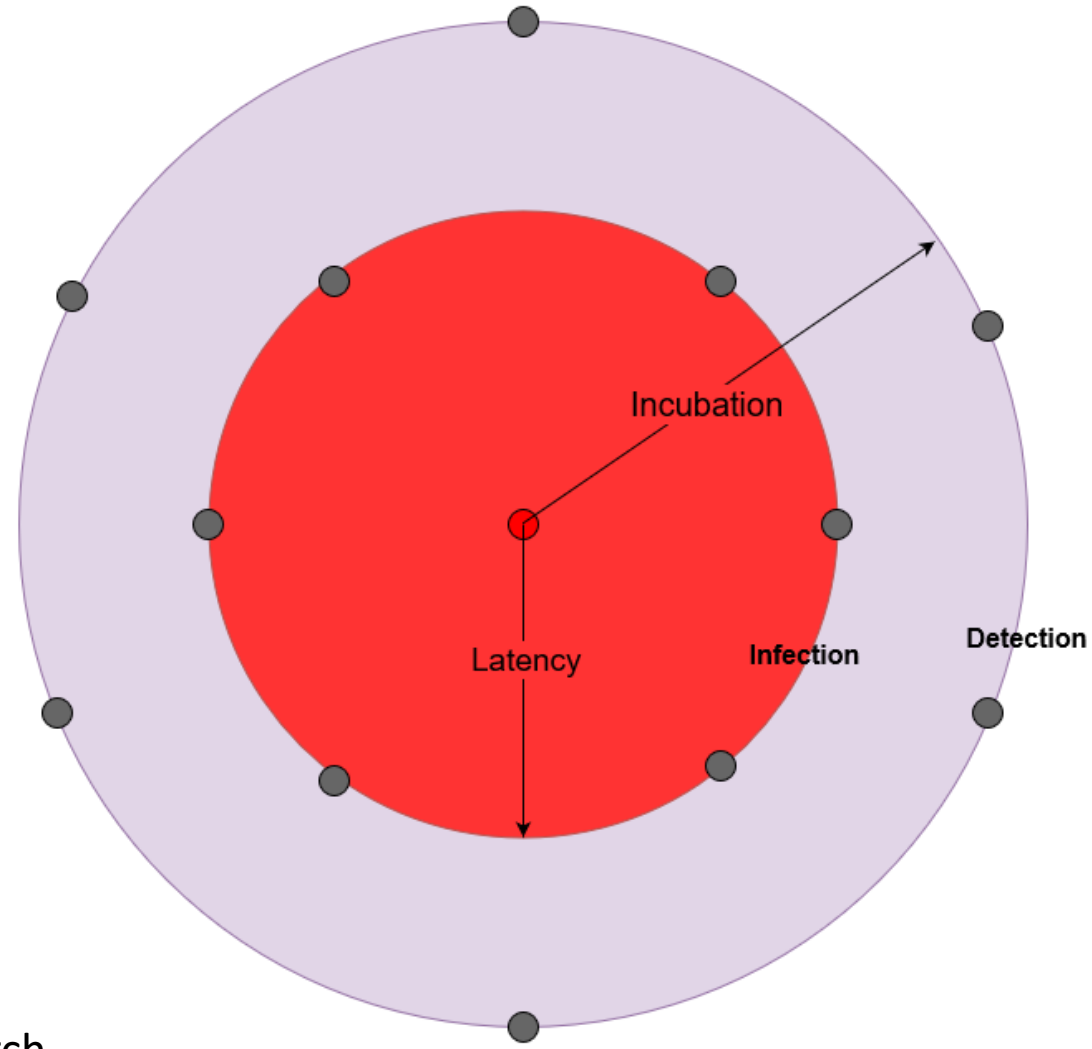


Temporal radius

How the spread acts on the temporal network

We identify an all-possible paths problem performed on a fixed radius – the radius of infection of length Latency, and the radius of detection of length Incubation.

The resulting search can be done efficiently.



The Longest Path in a Graph

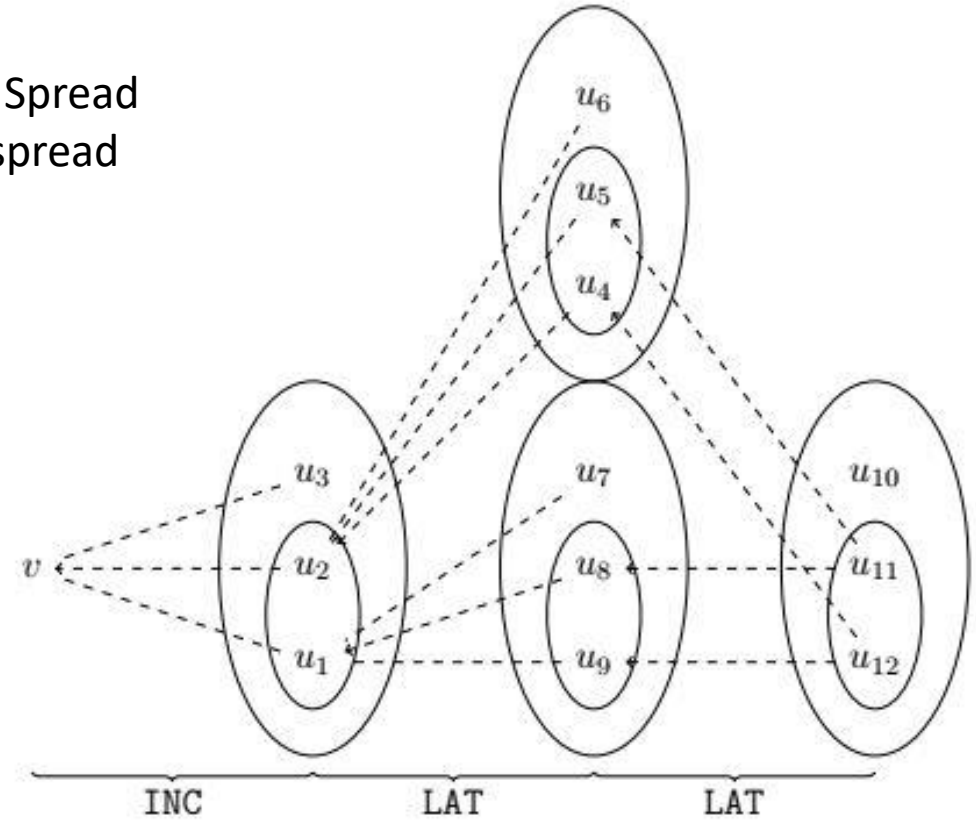
Known to be NP-hard.
Known to be FPT for parameter Length of Path.

This is where Incubation and Latency allow an efficient search.

Patient-zero

The goal: compute a complete History of Spread – i.e. trace the complete paths of illness spread from an infected node to its sources.

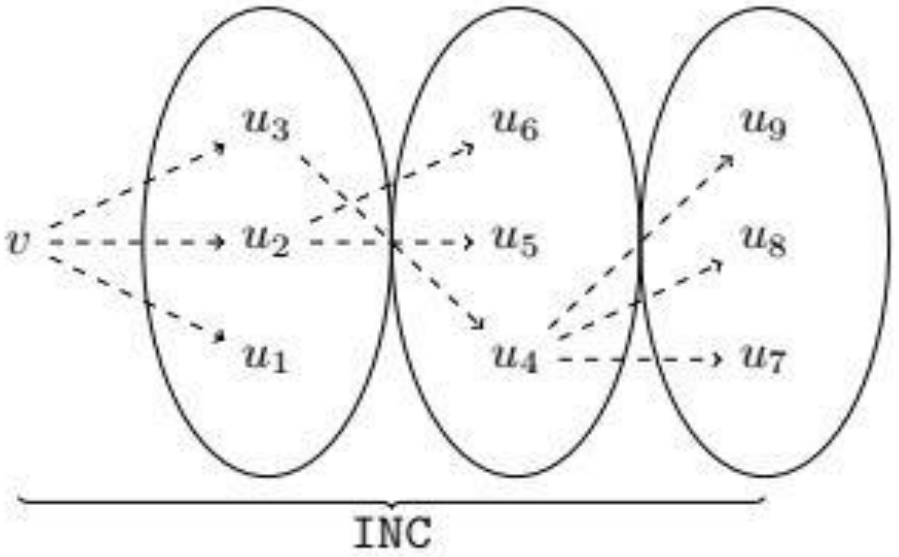
Method: perform searches backward on the temporal graph by making use of the Latency and Incubation time radii.



Classical Detection

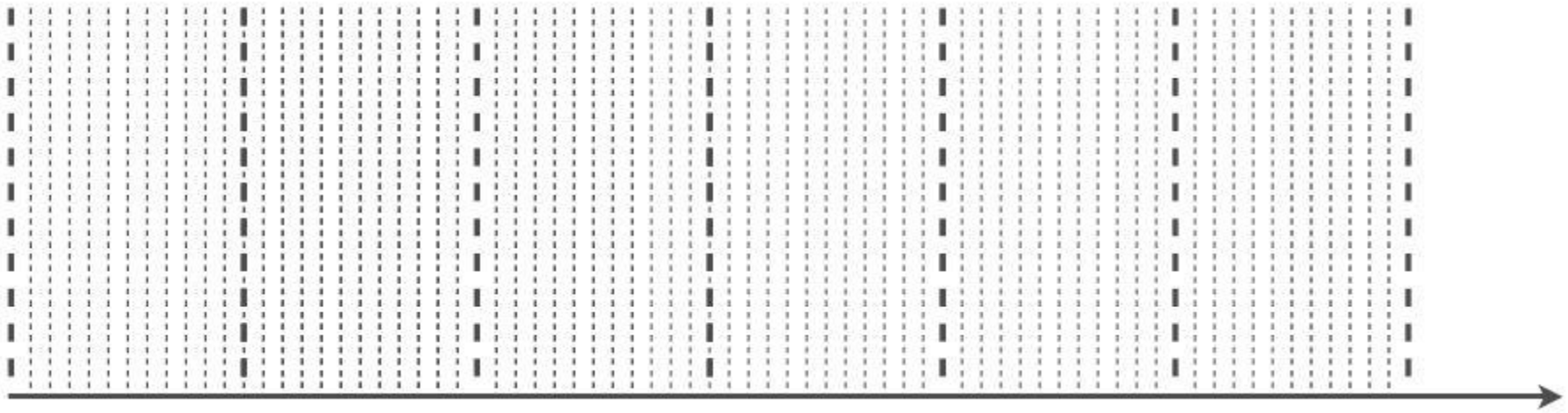
Detecting possible infected locations is straight-forward; search ahead on all of the nodes up to the Incubation radius.

- No need to search further, as further implies detected
- Any node found on such a path is potentially infected



Timeline

Time has direction, we observe discrete periods between trade. Locations are allowed to trade on certain moments in time, called rounds.



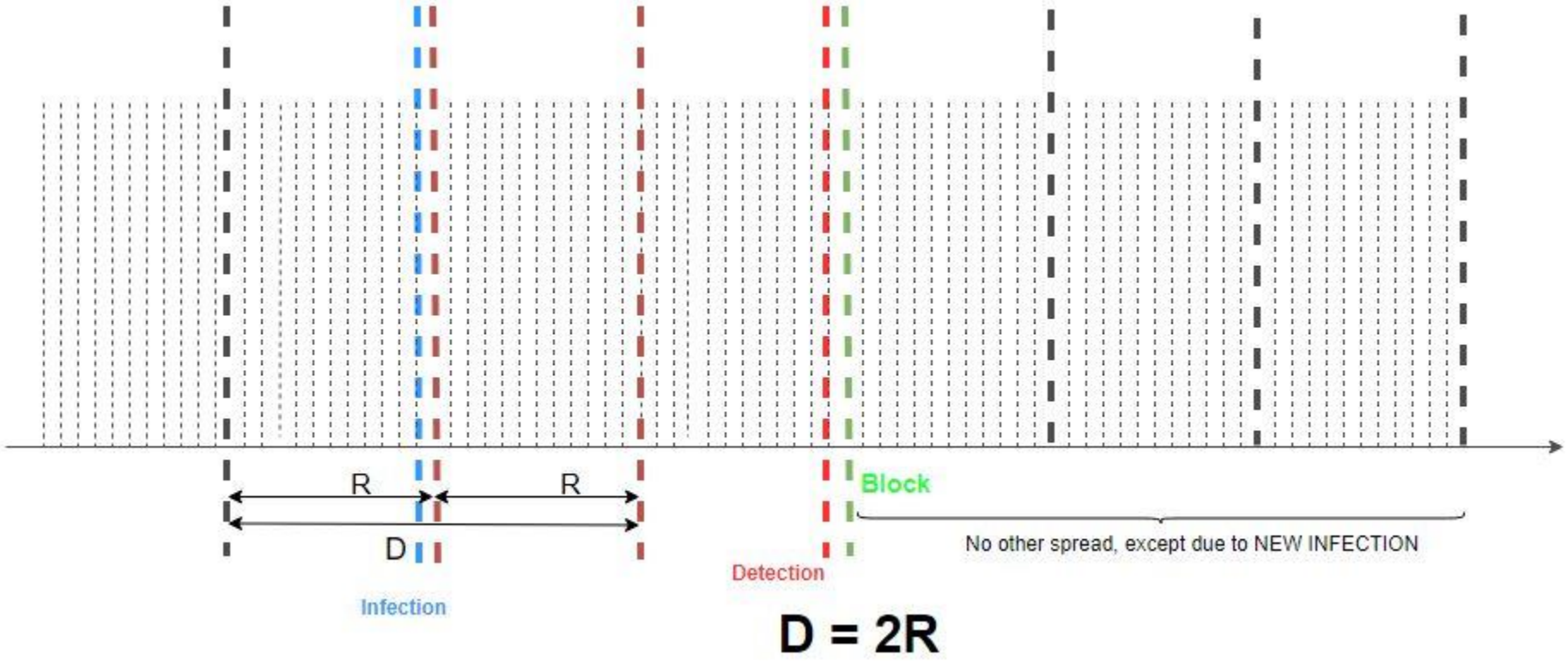
An analysis

- We analyse in what follows the relationship between

  - The interval between rounds of spread which is network-specific, and
  - The interval of detecting the infection, which is illness-specific.

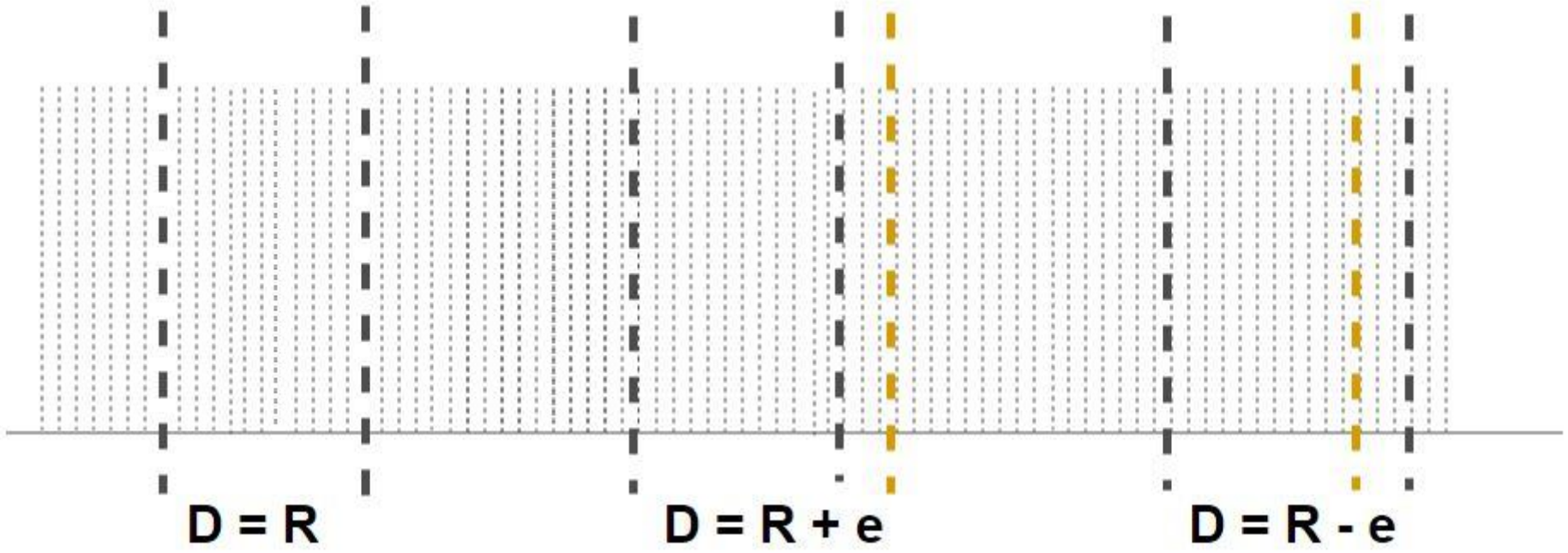
Example

What happens if the detection radius is two times the interval between rounds.



Three cases

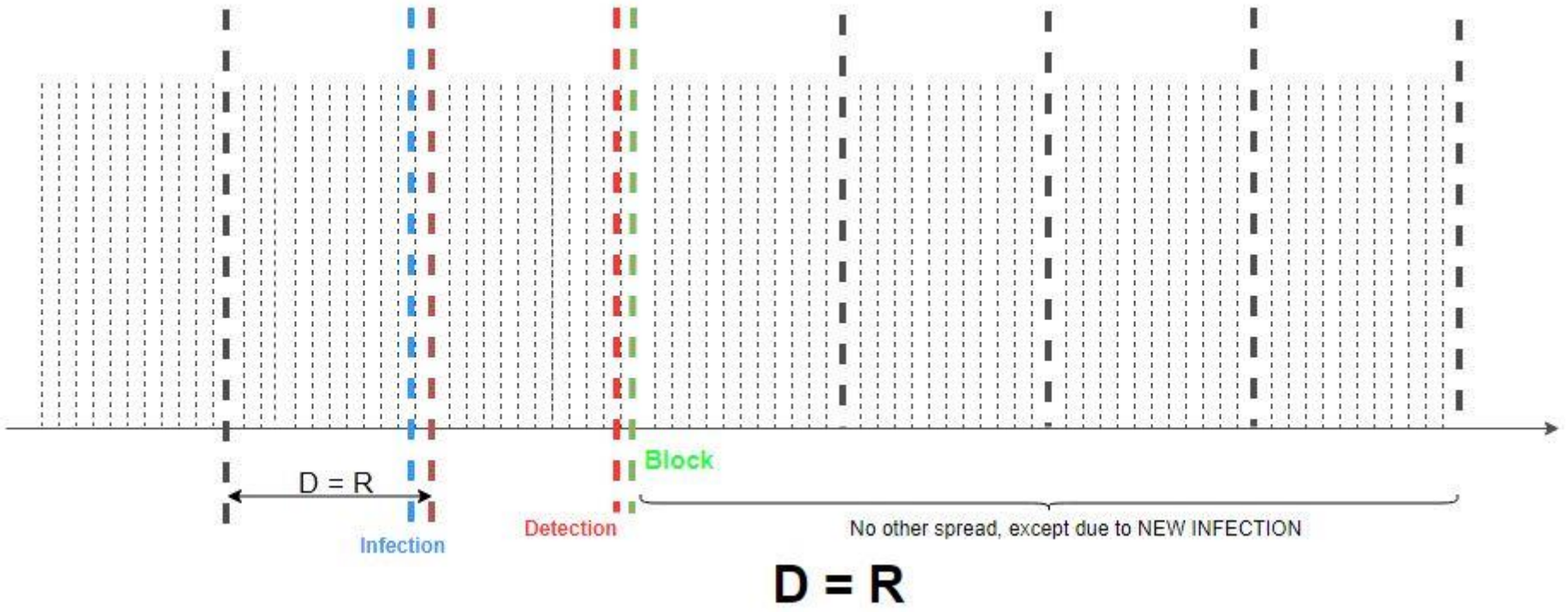
- Detection interval equals round interval
- Detection interval is smaller than the round interval
- Detection interval is greater than the round interval



I.

If Detection period is equal to the Round period

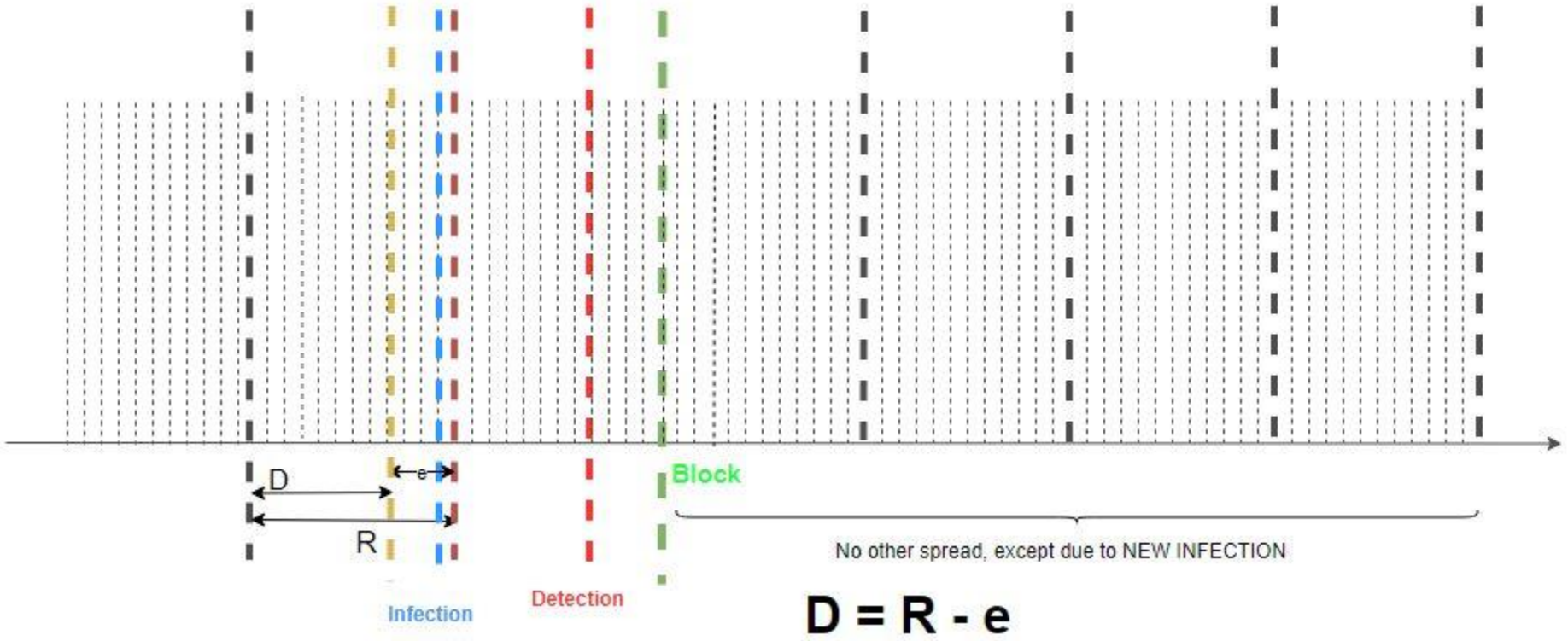
- No other spread with this source shall occur after <u>two rounds</u>



II.

If Detection period is less than the Round period

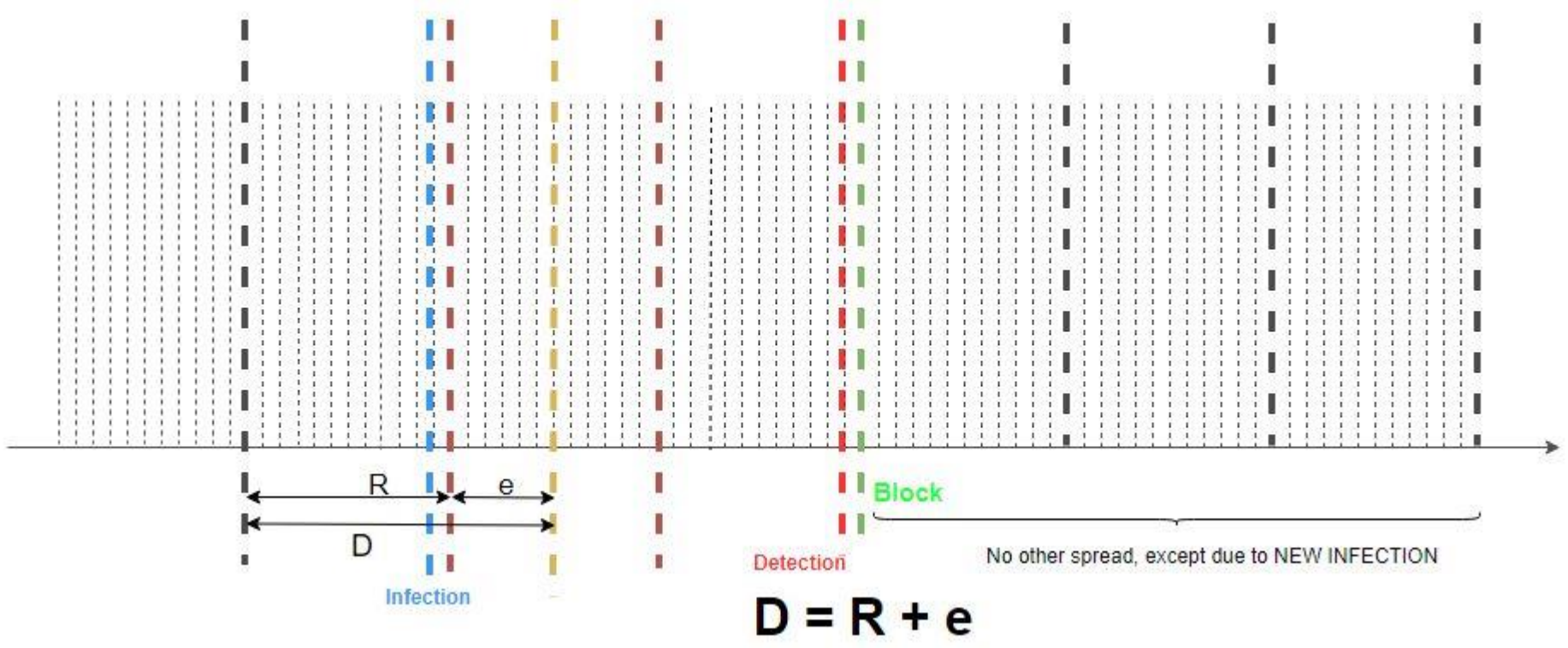
- No other spread with this source shall occur after <u>two rounds</u>



III.

If Detection period is greater than the Round period

- No other spread with this source shall occur after <u>three rounds</u>



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Thank you!