

Classic vs. connectivity-based control strategies in FMD and other viral epidemics

London's water distribution map (used by John Snow in his 1855 studies) and some of his plots, which identified the source of the cholera epidemic (the pump)

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Can we demonstrate network properties in epidemics?

a) In 1998, Watts & Strogatz predicted that epidemics should reveal network properties. Networks are composed of nodes connected by lines.

b) To demonstrate Network properties in epidemics, the data should meet two criteria: (i) **clinical** (observable) cases, and (ii) it should be known **when** and **where** the epidemic started (time and place of primary cases).

c) We have data that meet those criteria: (i) the **2001 Uruguayan foot-and-mouth disease (FMD) epidemics**, and (ii) the **2006 Nigerian avian influenza (AI H5N1)**.

"Infection" vs. "epidemic": Networks in exotic/emerging epidemics.

From abstract to measurable epidemic nodes: the **FMD** case

We investigated *not any cluster of FMD cases but disease clusters associated with a pre-existing, contact network.*

The FMD case density was highest within 7.5 km-radius circles centered on highway intersections (epidemic nodes).

Except the first 3 days, **epidemic nodes contained ~70% of all FMD cases.**

Assessing reproducibility –the AI case

Throughout the epidemic, **epidemic nodes** (31-km radius circles centered on road intersections and with the highest case density) **included ~60% of all AI cases.**

Both epidemics showed **nodes** –a property predicted by Network theory.

Finding the critical epidemic node in FMD epidemics

A **triple node** contained one of the 6 cases reported in the first 3 epidemic days, i.e., the first replication cycle of the virus (primary cases). By involving 3 highway intersections, this node offered the virus 3 opportunities to disseminate.

The index case was one of the 6 first reported cases. **Only primary cases with connectivity can disseminate** –regardless of whether the index case is one of them.

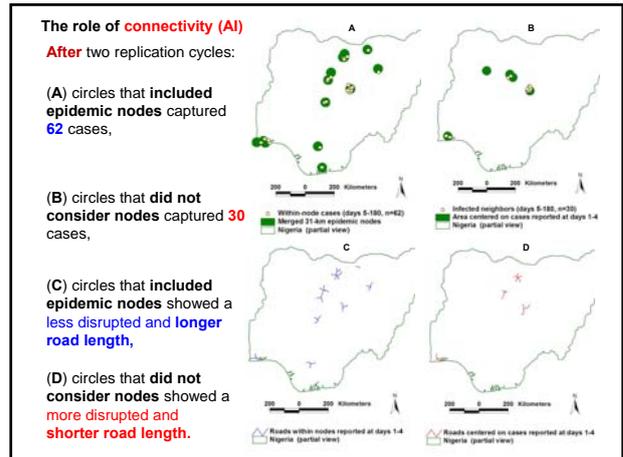
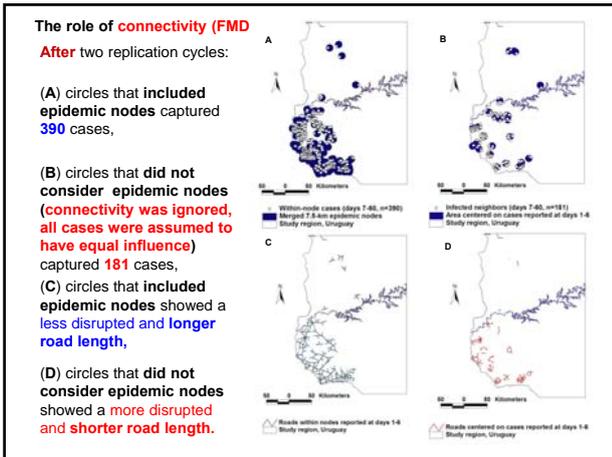
→The first reported case (the index case) is **not necessarily the most influential case.**

Epidemic dynamics: epidemic nodes "move" and "grow" fast

WITHIN 3 DAYS, the epicenter (centroid) of the FMD epidemic nodes **"moved" 39 km SW,** and epidemic nodes **"grew" 48.7 times** (from 3 to 56 individual nodes).

The **second epidemic period** (days 4-6) only involved **NEW nodes** –a property predicted by CN theory.

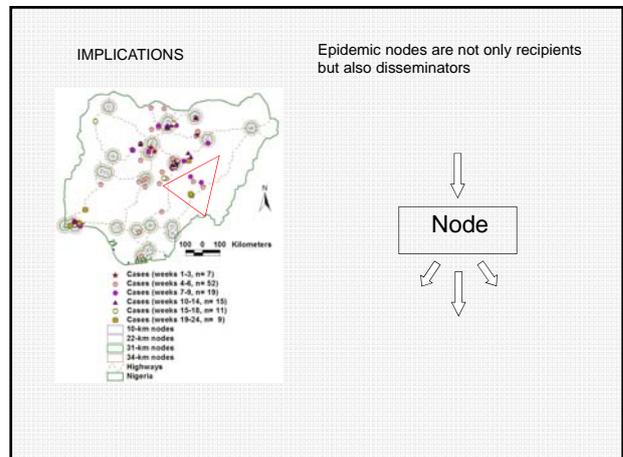
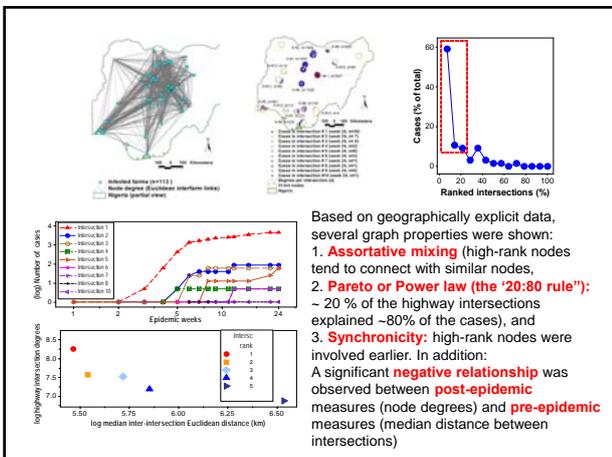
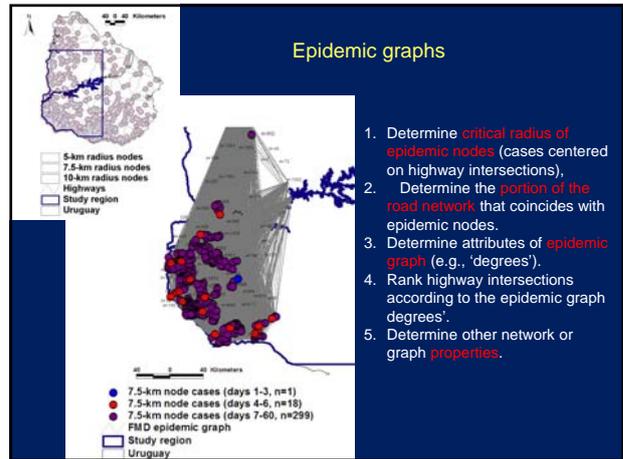
The node **epicenter** also moved (700 km) in the **second** period of the AI epidemic



Not all disease clusters are equal:
 → **connected** disease clusters are **more influential**

Because connected disease clusters (nodes) "move" rapidly,
 → **static clustering analysis is not adequate to assess epidemic dynamics**

→ **connectivity should be measured in each viral replication/transmission period.**



Conclusions

- Epidemic nodes and links (*connectivity*) can be measured with *geo-referenced data*.
- Because *connectivity predates contacts*, in rapidly disseminating epidemics, connectivity is likely to be a pre-existing condition, e.g., road networks can be explored *before epidemics occur*.
- The combination of *population density* (animal and human) and *connecting structures* likely to act as 'epidemic nodes' may be determined before epidemic occur.