EPICENTER: Laboratory for a network science approach to predict and control the spread of infectious diseases

Background
Few events disrupt society and cause economic loss as severely as an out-of-control infectious disease. Terrorist activities or natural causes can produce an epidemic that may result in human deaths, the disposal of herds, and the destruction of crops. Fundamental to EPICENTER’s mission is the conviction that epidemic dynamics and intervention strategies must be derived while accounting for underlying complex networks that describe multiple and dynamic interconnections among involved systems.

Description
EPICENTER, a laboratory within Kansas State University’s College of Engineering, provides resources to build, analyze, and simulate data-driven computational models for biomedical and biological systems represented as complex networks.

Research at EPICENTER challenges scientific boundaries by addressing the impact of (1) heterogeneity, (2) interdependence, and (3) stratification of networks in spreading processes. These three characteristics abound in natural and man-made infrastructures and networks, but fundamental questions remain unanswered regarding interconnected and stratified/multilayer networks.

Projects within EPICENTER
EPICENTER has successfully conducted several research projects since its inception in 2007. Current projects include:

*Predictive models of infectious diseases*: This project aims to develop innovative multiscale computational models and tools to describe potential transmission cycles of zoonotic pathogens that could be introduced into the United States. Data generated by these models will be used to produce an operationally relevant predictive model that estimates the timing and spatial extent of emerging disease and the transmission risk to humans. Studied diseases include Ebola, Rift Valley fever, and Japanese Encephalitis.

*Spreading processes over multilayer and interconnected networks*: The research goal is to establish mathematical tools and techniques in order to understand the role of multilayer and interconnected topologies in spreading processes. For example, a multilayer network is a physical contact network in which a disease can propagate among individuals and an online information dissemination network in which information can propagate among those same individuals. In zoonotic diseases, interconnected networks include the network of animals and the network of humans in which a virus can transfer from one population (network) to another.

Integrated models of disease spread, supply chain logistics, and communication networks: The objective of this project is to develop integrated models that capture interdependencies between disease dynamics, supply chain logistics, and communication networks. For example, the spread of disease is influenced by the movement of animals, plants, and food products through the supply chain. Effective management of this movement and deployment of countermeasures such as vaccines, require effective risk and crisis communication plans that engage multiple stakeholders. Stakeholders also constitute a network through which information is transmitted. The integrated modeling approach is expected to yield new insight in order to prevent, mitigate, and respond to infectious disease outbreaks.

Relevance
The National Agricultural Biosecurity Center (NABC), the Institute for Computational Comparative Medicine (ICCM), the Center of Excellence for Emerging and Zoonotic Animal Diseases (DHS CEEZAD), the planned National Bio and Agro-Defense Facility (DHS NBAF), and EPICENTER are all located in Manhattan, Kansas, thus making Kansas the national leader in developing countermeasures to naturally-occurring and intentionally-introduced plant, animal, human, and zoonotic diseases.

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The EPICENTER laboratory at Kansas State University provides resources for a network science approach to predict and control the spread of infectious diseases. Few events disrupt society and cause economic loss as severely as an out-of-control infectious disease. Epidemic dynamics and intervention strategies must be derived while accounting for the underlying complex networks that describe multiple dynamic interconnections among involved systems.

**Motivations:** Terrorist activities or natural causes can produce epidemics that may result in human deaths, the disposal of herds, and the destruction of crops. Lack of models to predict epidemic evolution and to optimally allocate resources can result in wasted resources and limited success in impeding the epidemic.

**Solution:** EPICENTER provides resources to build, analyze, and simulate data-driven computational models for biomedical and biological systems represented as complex networks. Research at EPICENTER challenges scientific boundaries by addressing the impact of (1) heterogeneity, (2) interdependence, and (3) stratification of networks in spreading processes. These three characteristics abound in natural and manmade infrastructures and networks, but fundamental questions remain unanswered for interconnected and stratified/multilayer networks.

**Impact:** These network models are used to produce operationally relevant predictive models that estimate the timing and spatial extent of emerging disease and the transmission risk to humans. Studied diseases include Ebola, Rift Valley fever, and Japanese Encephalitis. Data is further integrated into models that capture interdependencies between disease dynamics, supply chain logistics, and communication networks, thereby yielding new insight in order to prevent, mitigate, and respond to infectious disease outbreaks.

**Expertise:** Network science, spreading processes, optimization.