U.S. Army Research, Development and Engineering Command

Time Series Modeling of Army Mission Command Communication Networks: An Event-Driven Analysis

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Laura Marusich
Norbou Buchler
U.S. Army Research Laboratory

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Motivation

- Transition to Network-Enabled Operations
- Vast number of potential collaborations
- Vast amount of available information
- C2 networks increasingly dependent upon robust human interactions for timely decision-making
- Can we predict patterns of communication occurring across time?

Approach

- **Examine the communication record of a fully-networked Army coalition command and control organization**
  - Two echelons of command at the Division and Brigade levels over a two-week military scenario exercise
- **Use communication record to construct social network at each time point of the exercise**
- **Use time series analysis methods to predict number of communication links at a given time point**

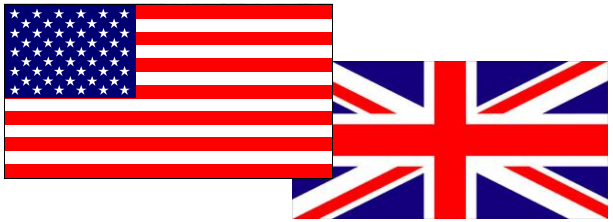
Exercise Event

U.S. Army simulation-based training event

- Two week experiment/exercise at Mission Command Battle Laboratory, Ft. Leavenworth
  - Week 1 – lethal operations
  - Week 2 – civil-military operations

- Participating Groups
  - U.S. Division HQ
  - U.K. Brigade Combat Team
  - Two U.S. Brigade Combat Teams (Not fully staffed)

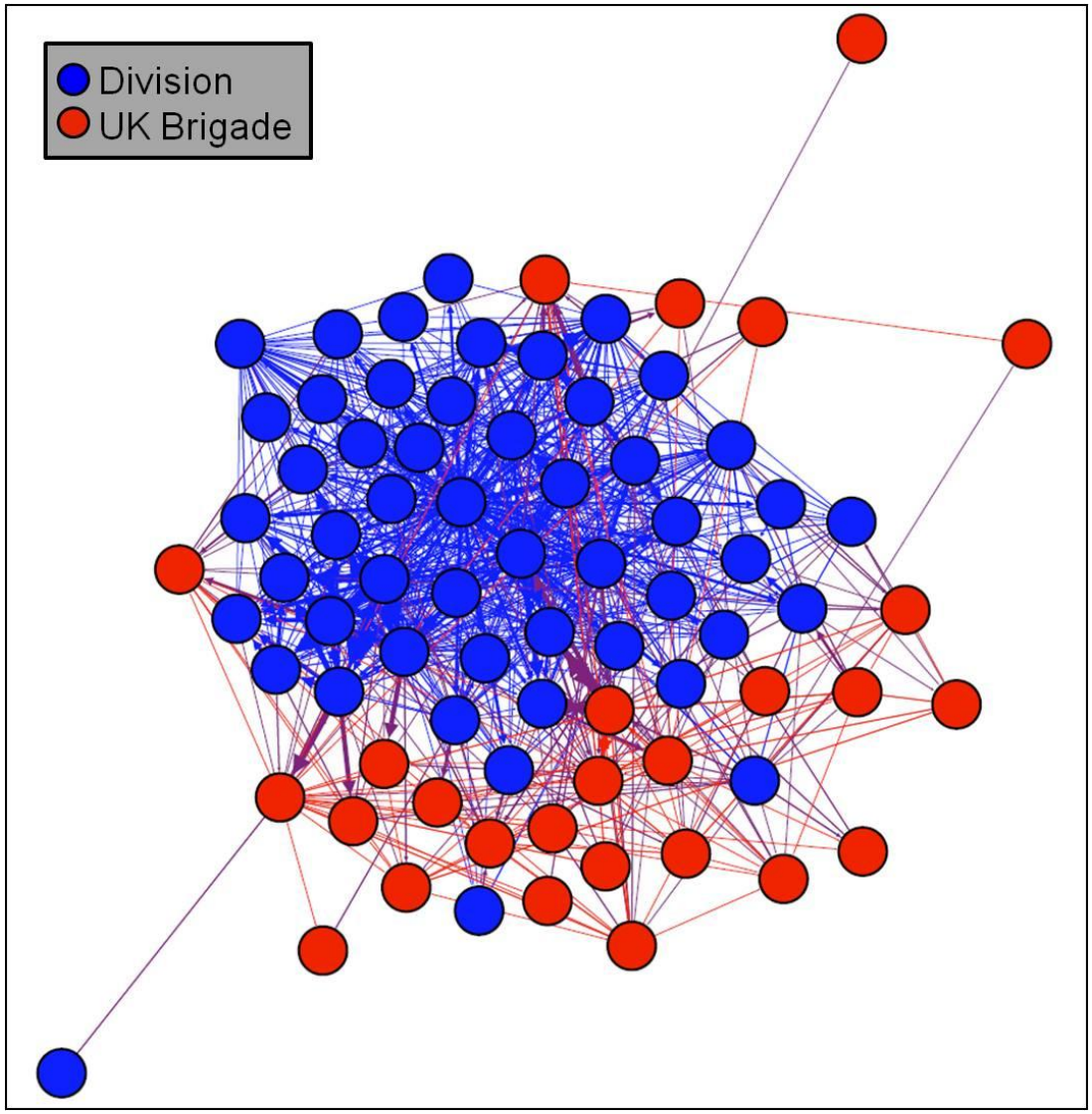
- Focus: U.S./U.K interoperability



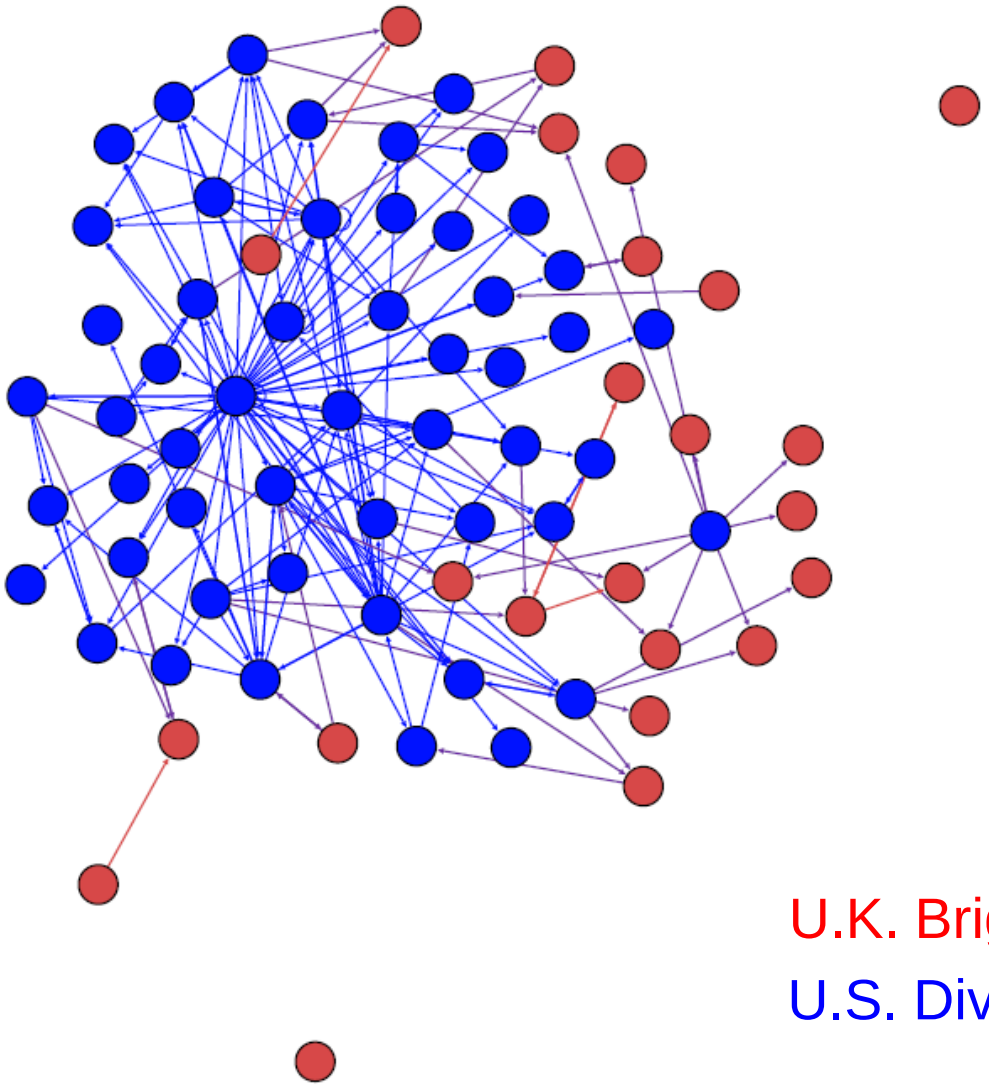
Communications Data

- **Participants primarily used telephone (VoIP) and email to communicate**
- **Collected three pieces of information:**
  - Sender
  - Receiver
  - Timestamp
- **Aggregated the communications into intervals of one hour**
- **Constructed communications networks for each interval**

Overall Network



Network by Hour

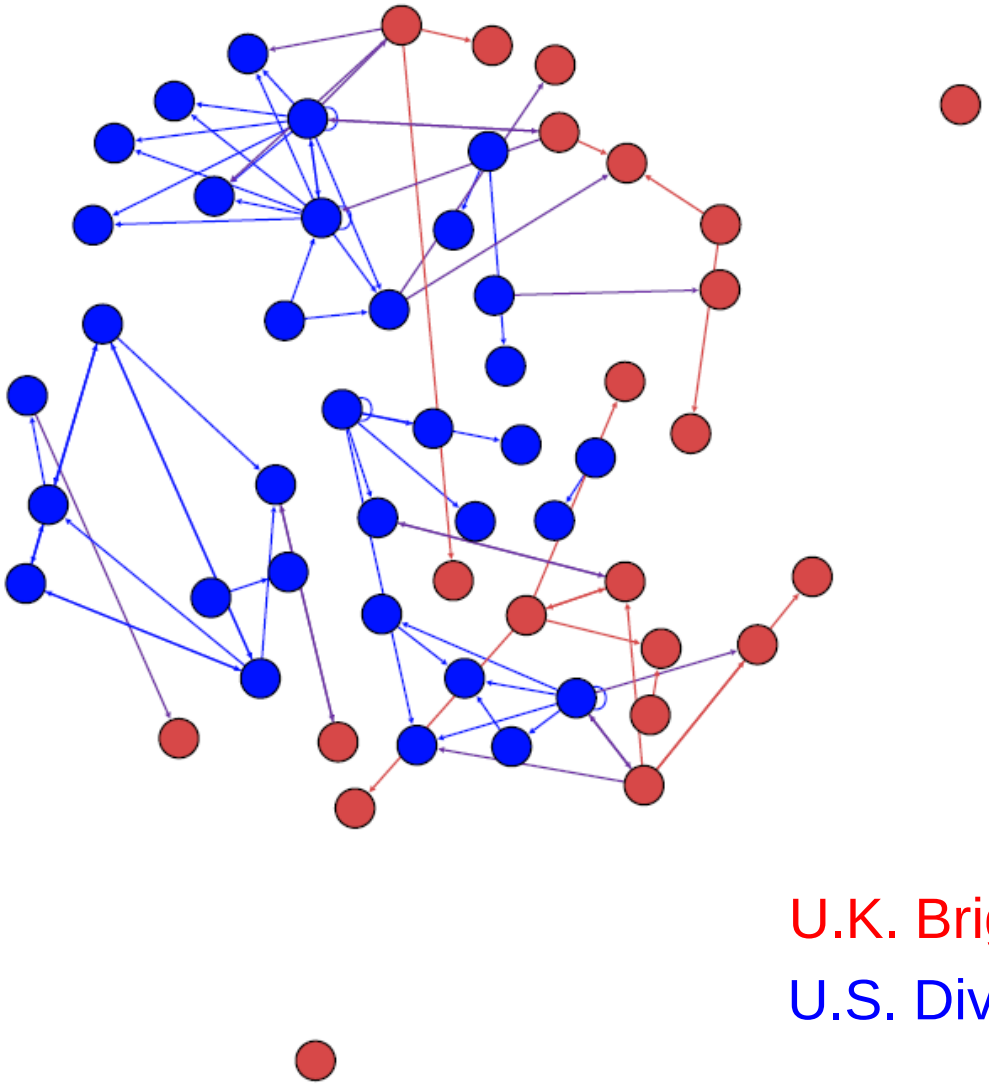


Hour 1

U.K. Brigade

U.S. Division

Network by Hour

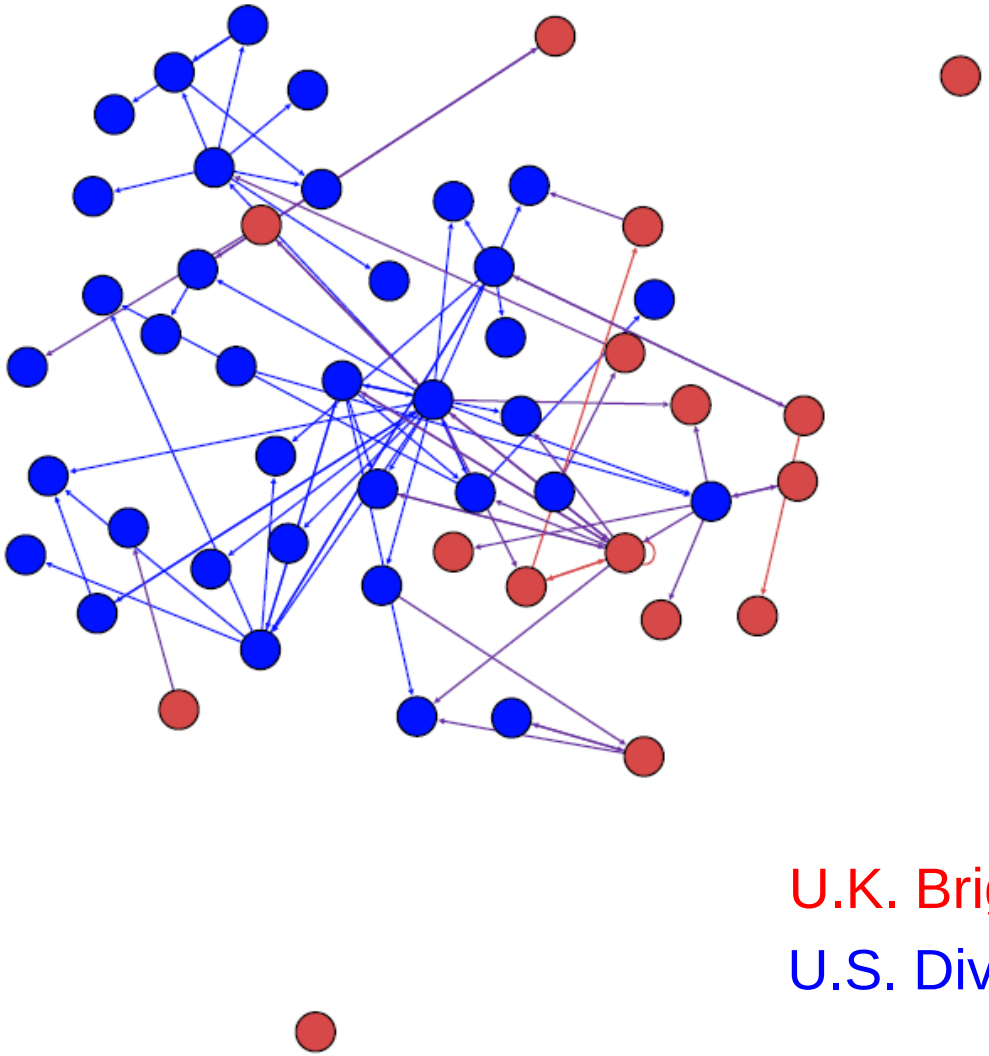


Hour 2

U.K. Brigade

U.S. Division

Network by Hour

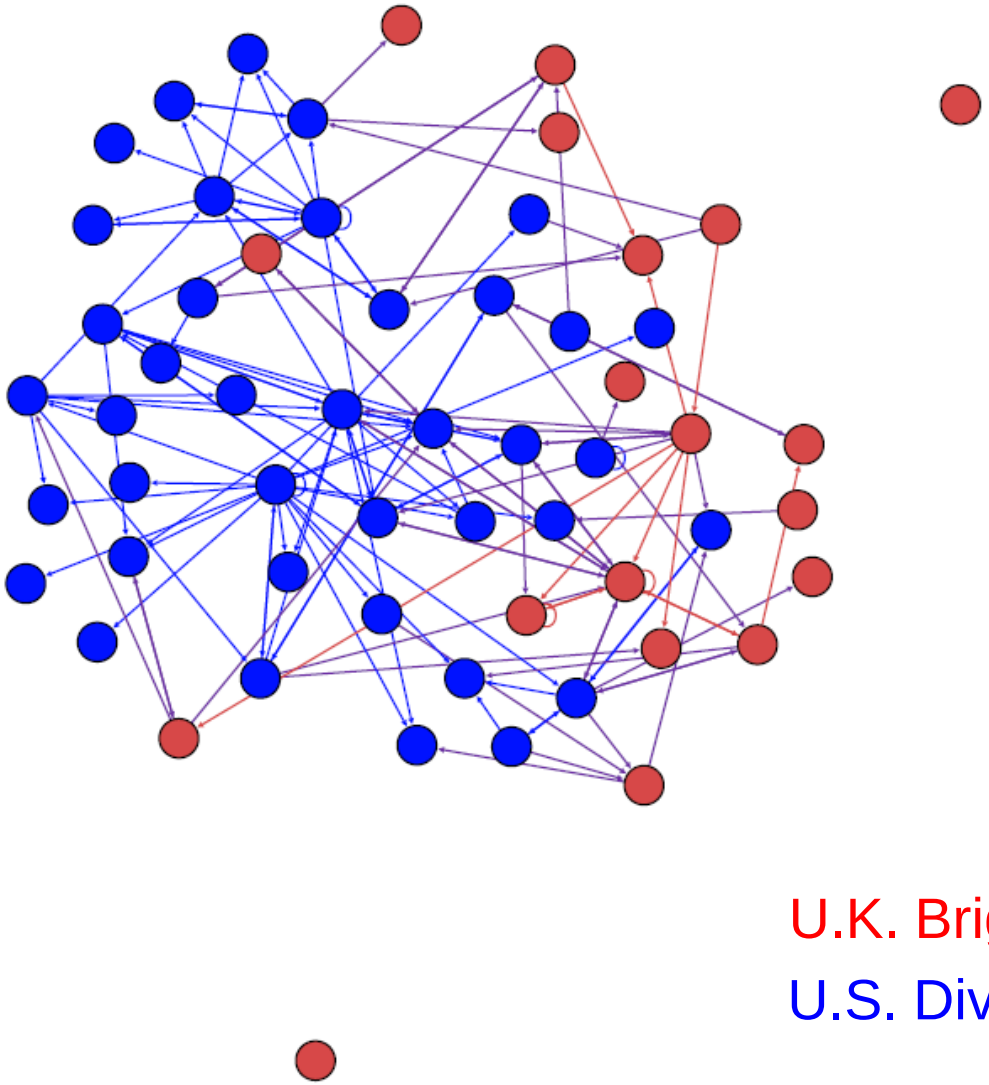


Hour 3

U.K. Brigade

U.S. Division

Network by Hour

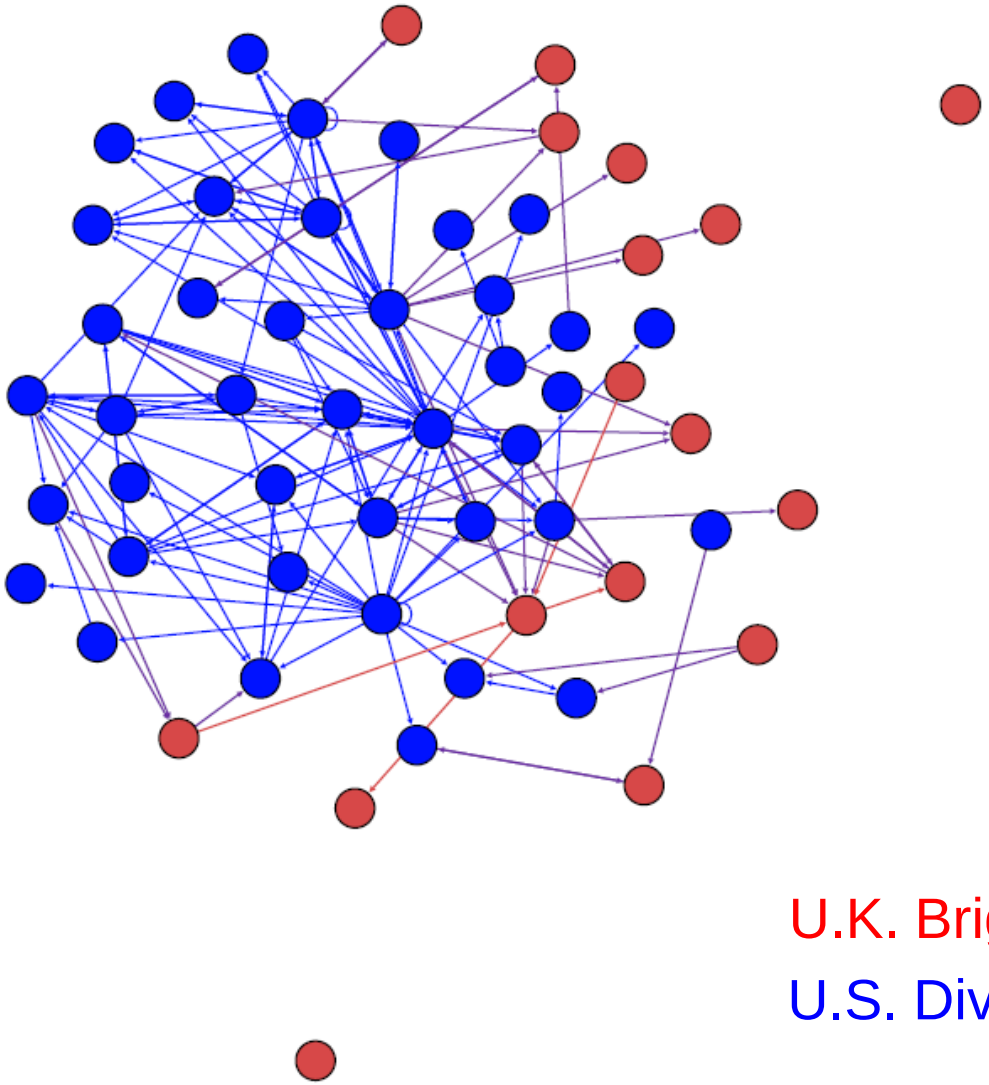


Hour 4

U.K. Brigade

U.S. Division

Network by Hour

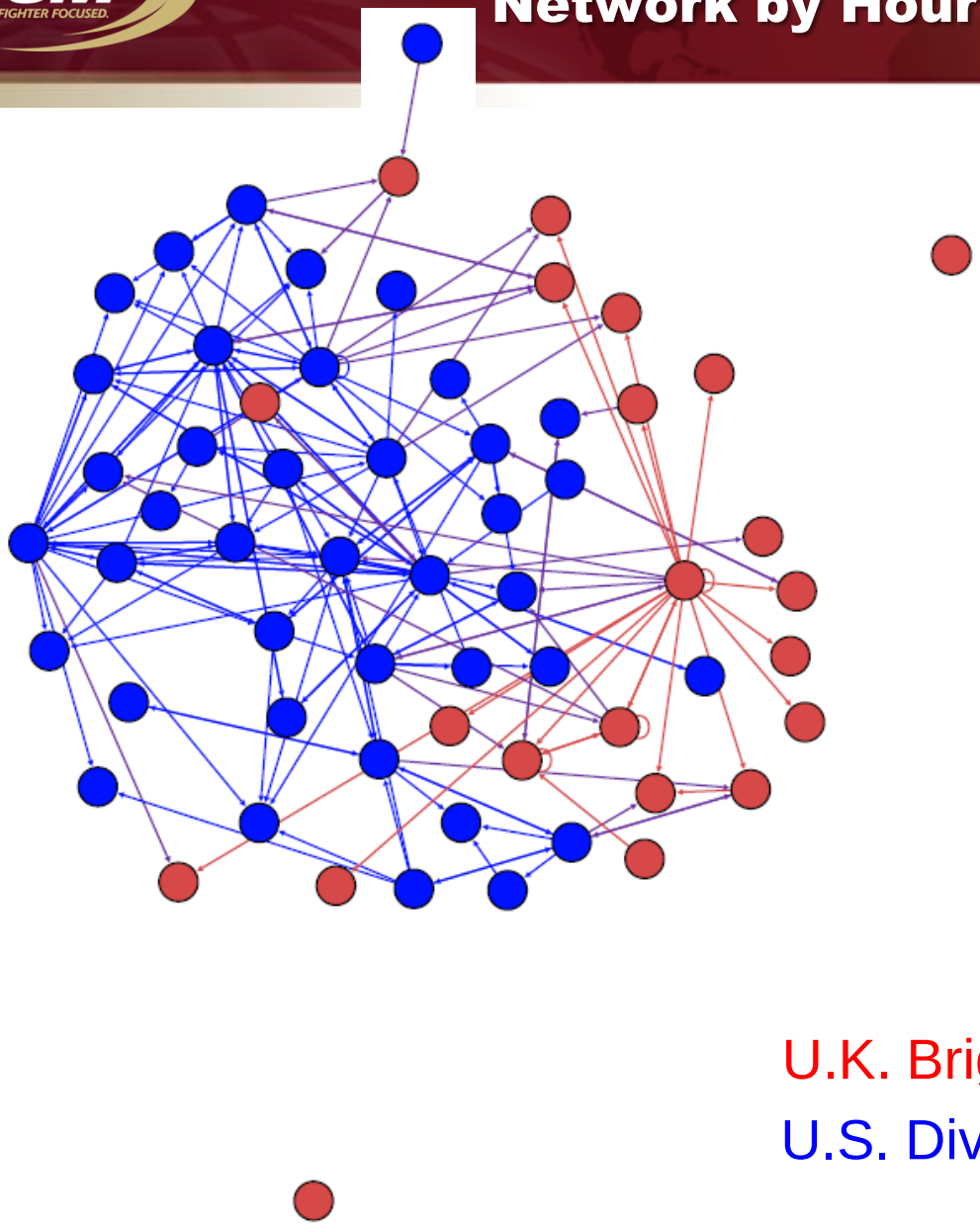


Hour 5

U.K. Brigade

U.S. Division

Network by Hour

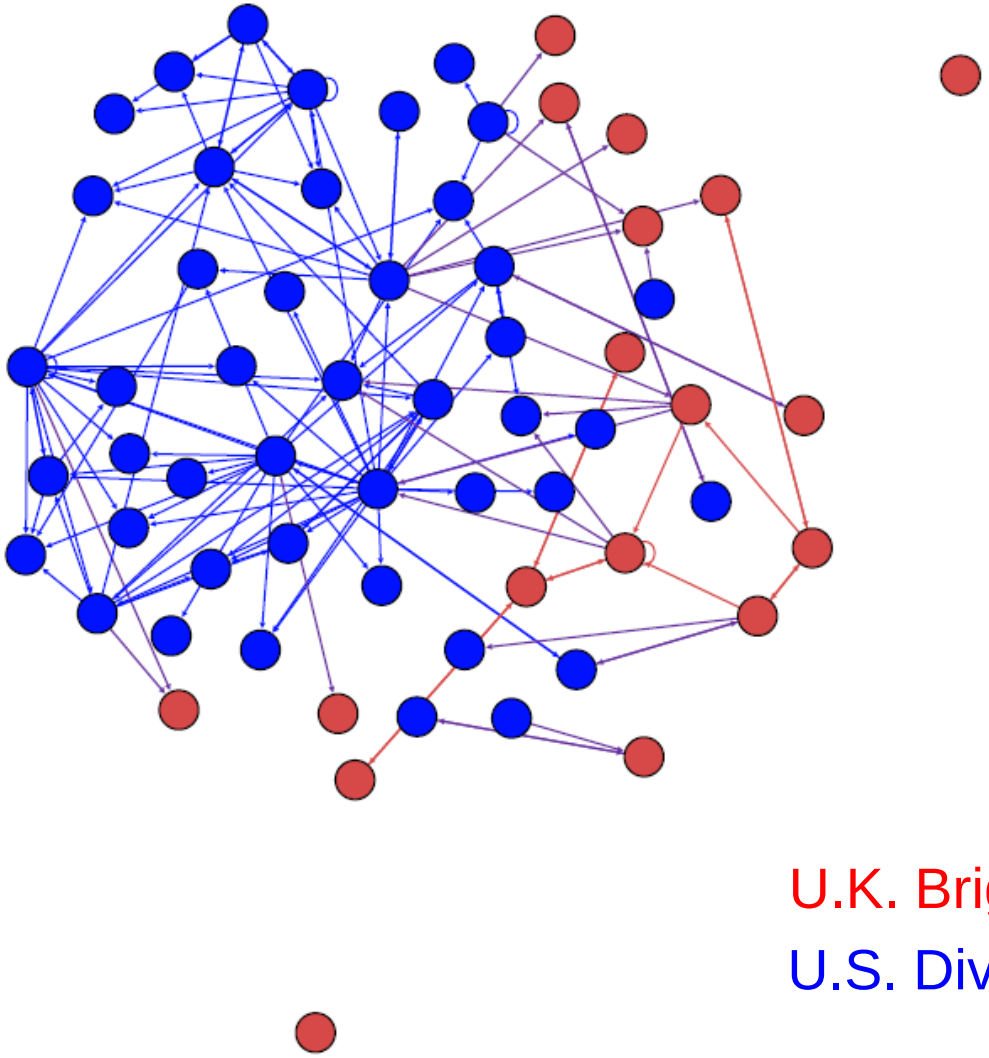


Hour 6

U.K. Brigade

U.S. Division

Network by Hour

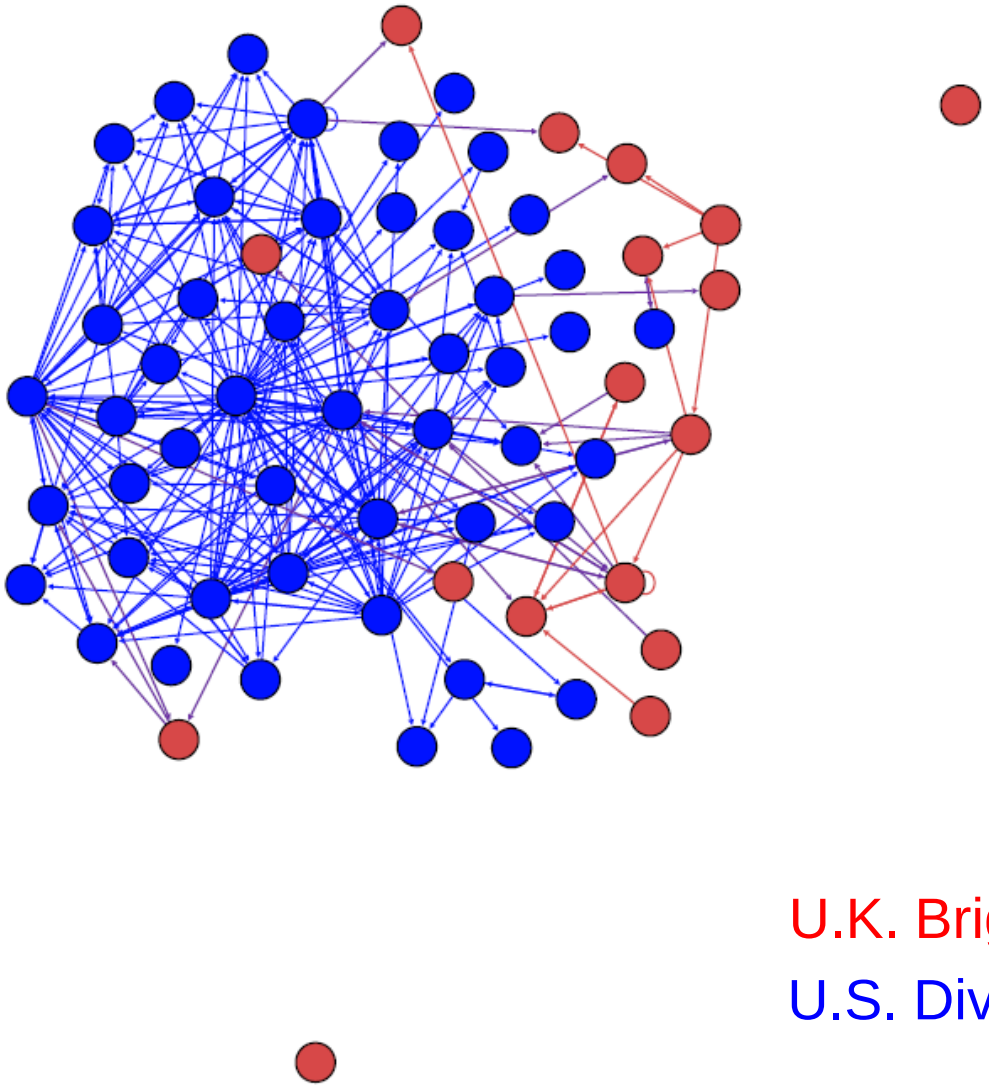


Hour 7

U.K. Brigade

U.S. Division

Network by Hour

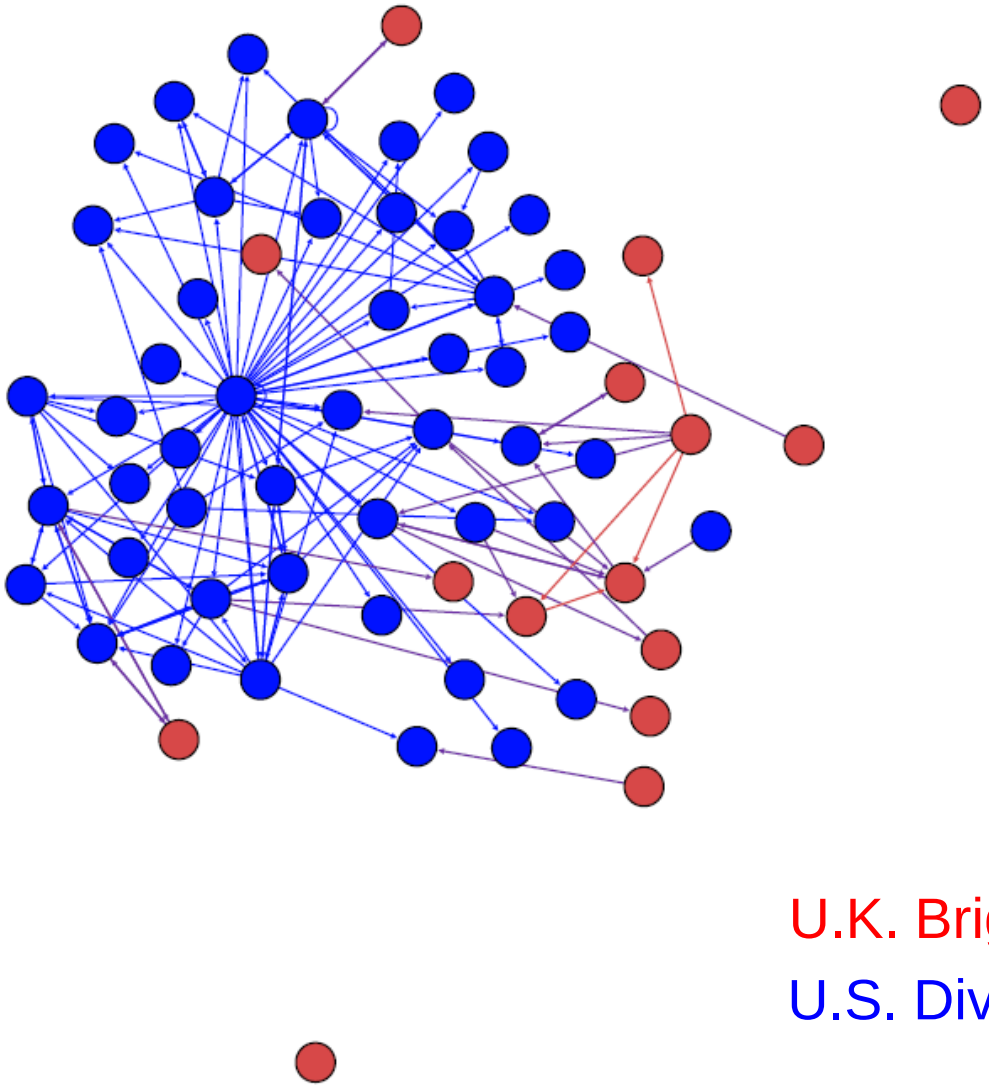


Hour 8

U.K. Brigade

U.S. Division

Network by Hour

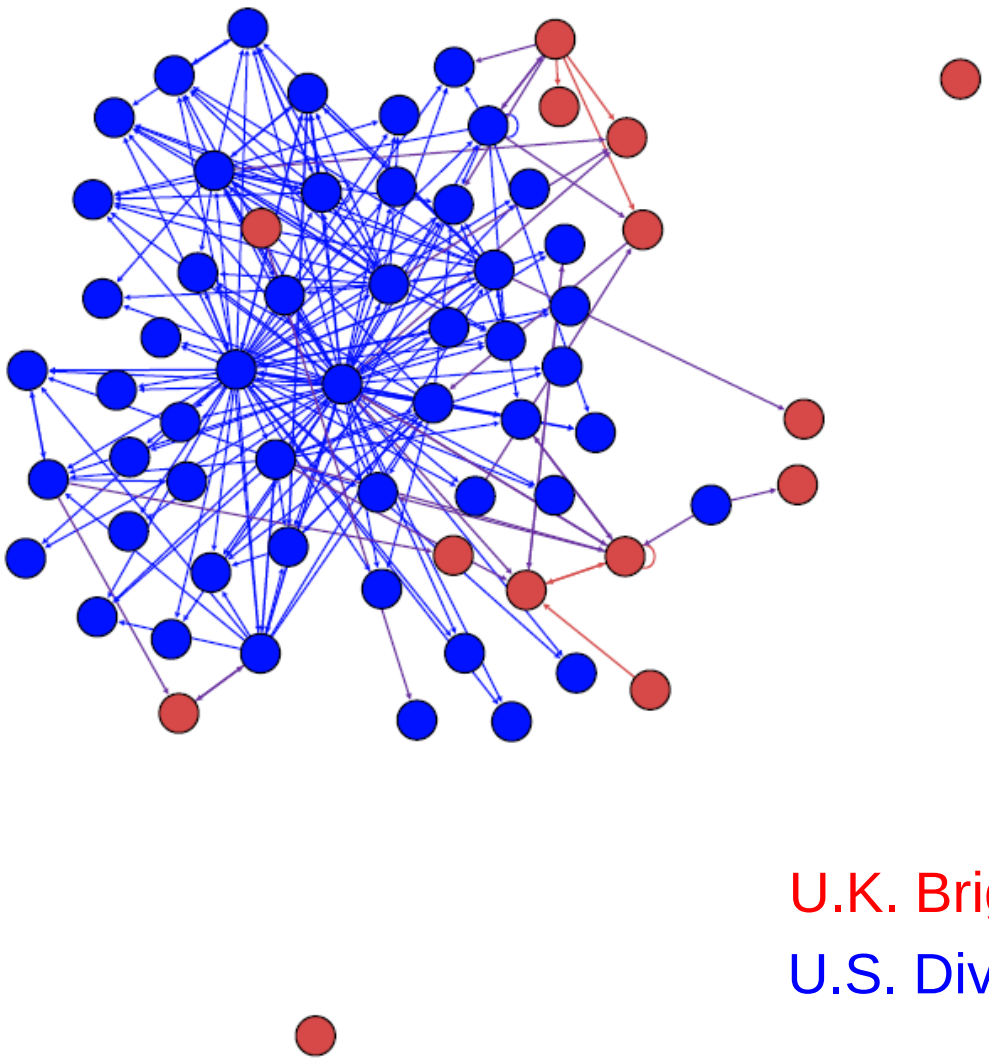


Hour 9

U.K. Brigade

U.S. Division

Network by Hour

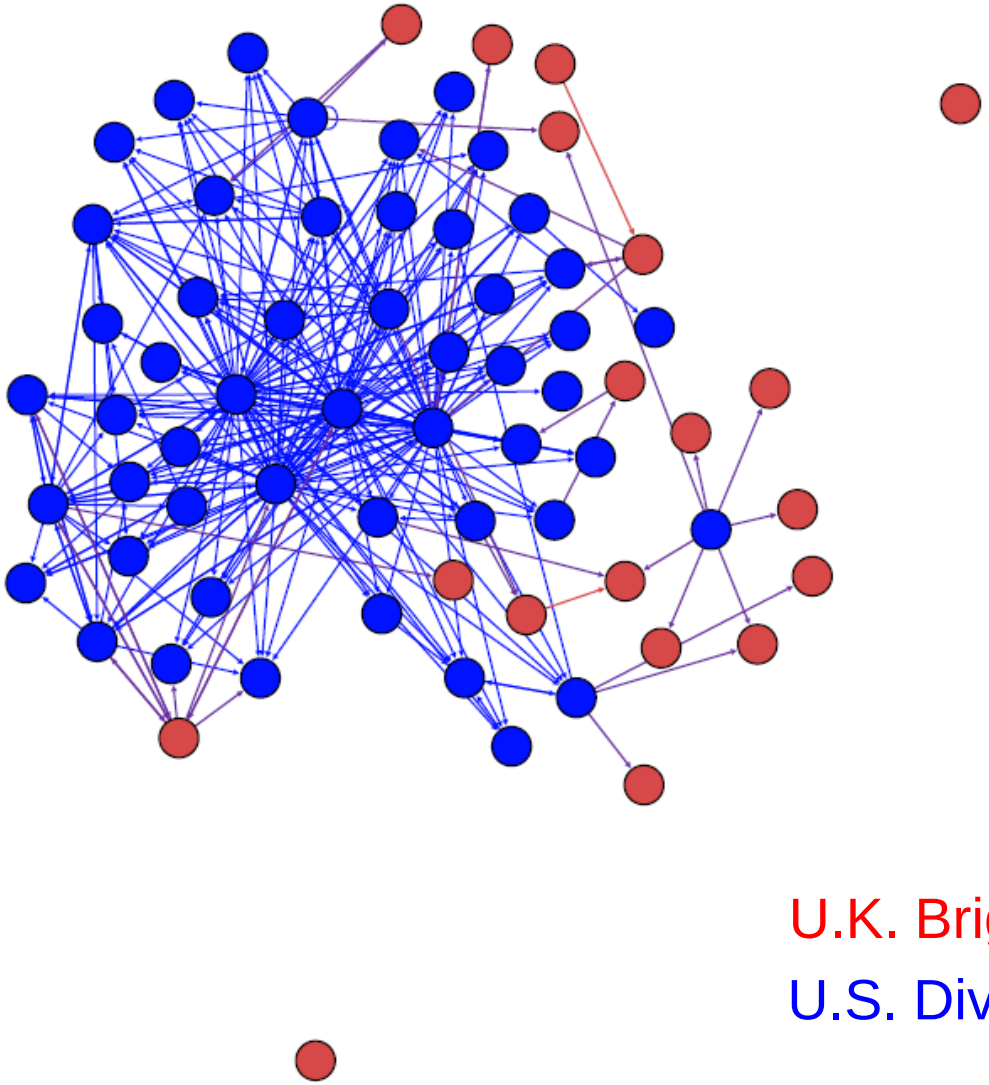


Hour 10

U.K. Brigade

U.S. Division

Network by Hour

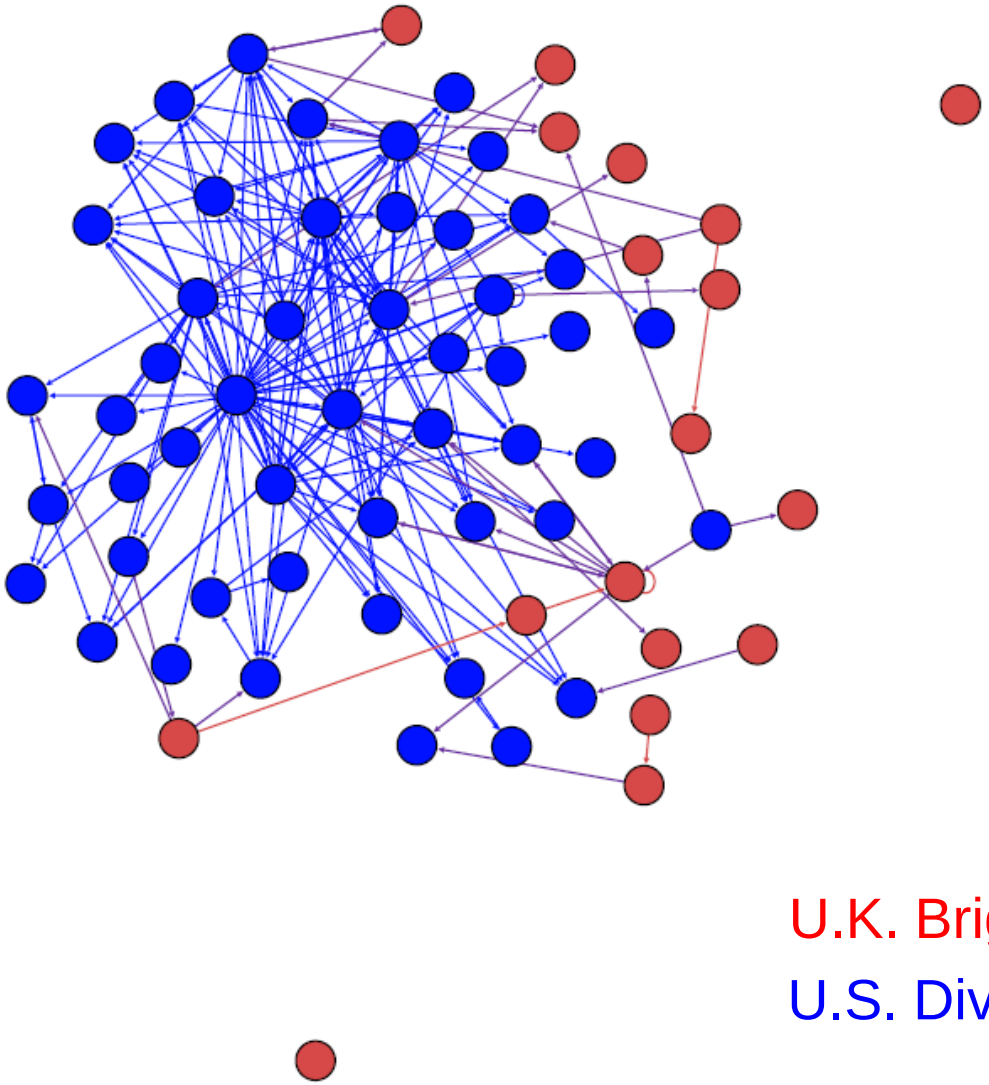


Hour 11

U.K. Brigade

U.S. Division

Network by Hour

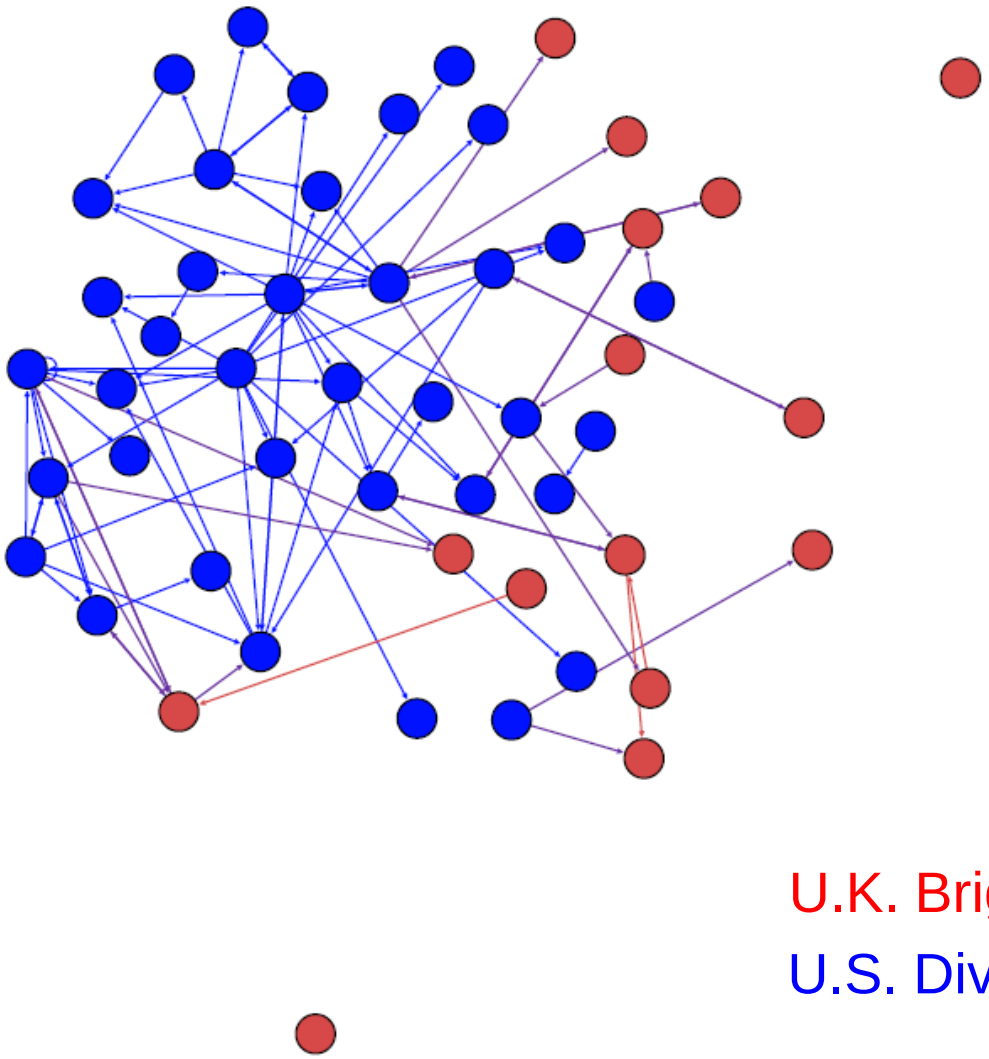


Hour 12

U.K. Brigade

U.S. Division

Network by Hour

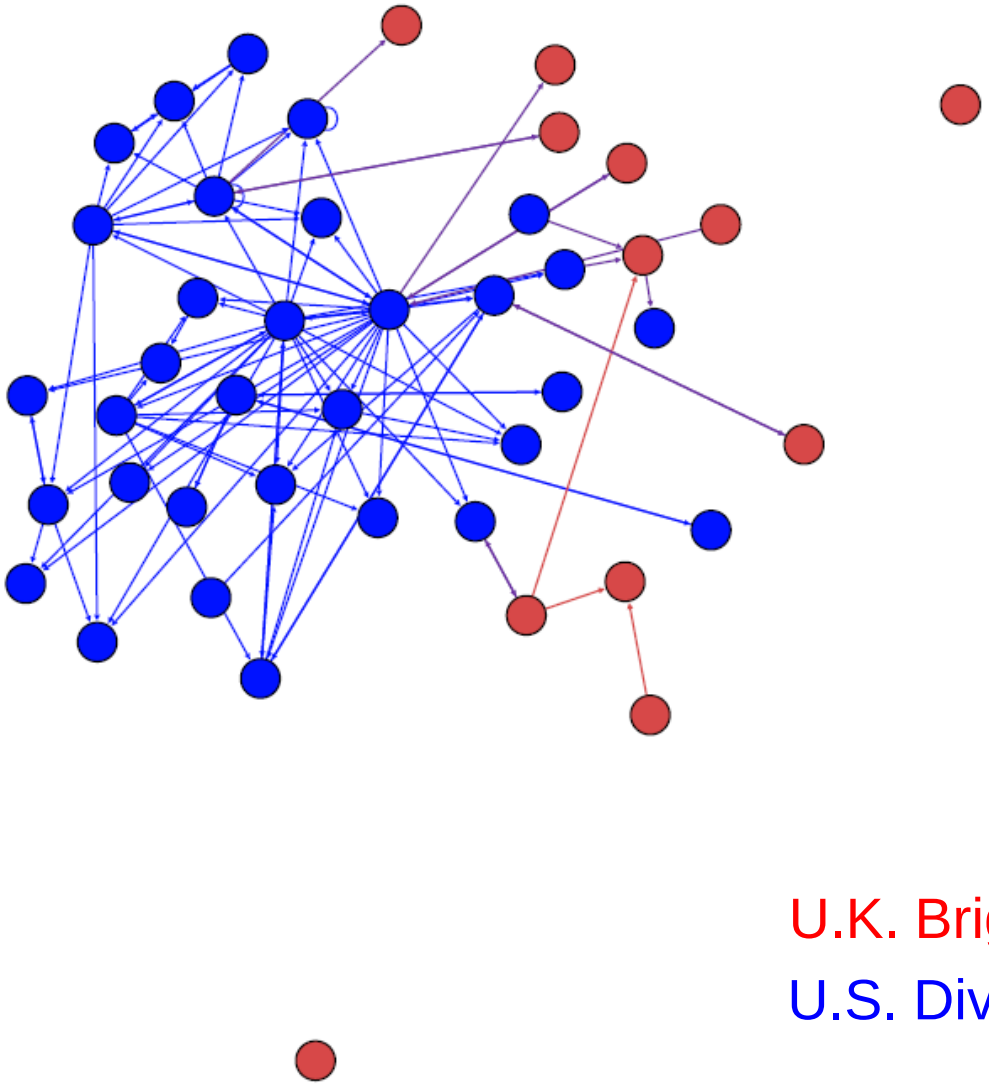


Hour 13

U.K. Brigade

U.S. Division

Network by Hour

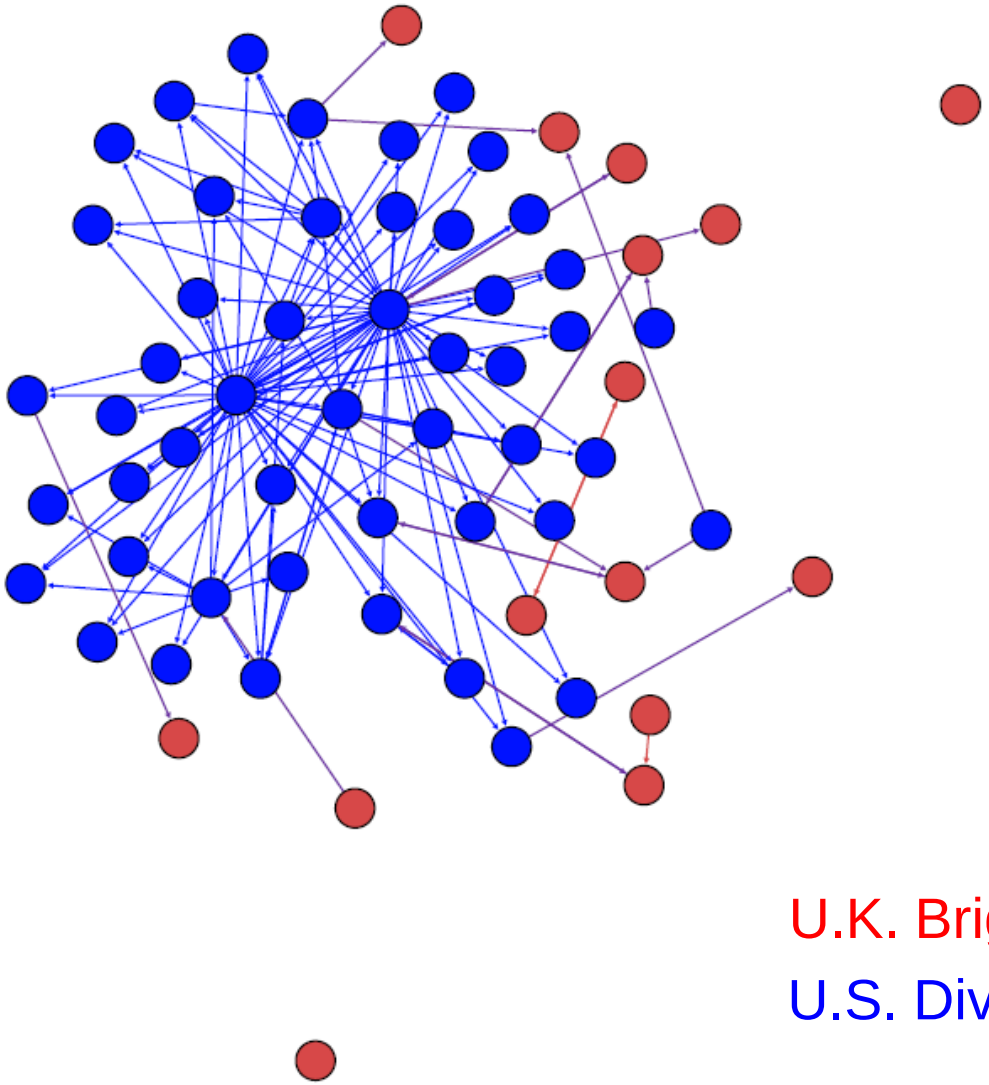


Hour 14

U.K. Brigade

U.S. Division

Network by Hour

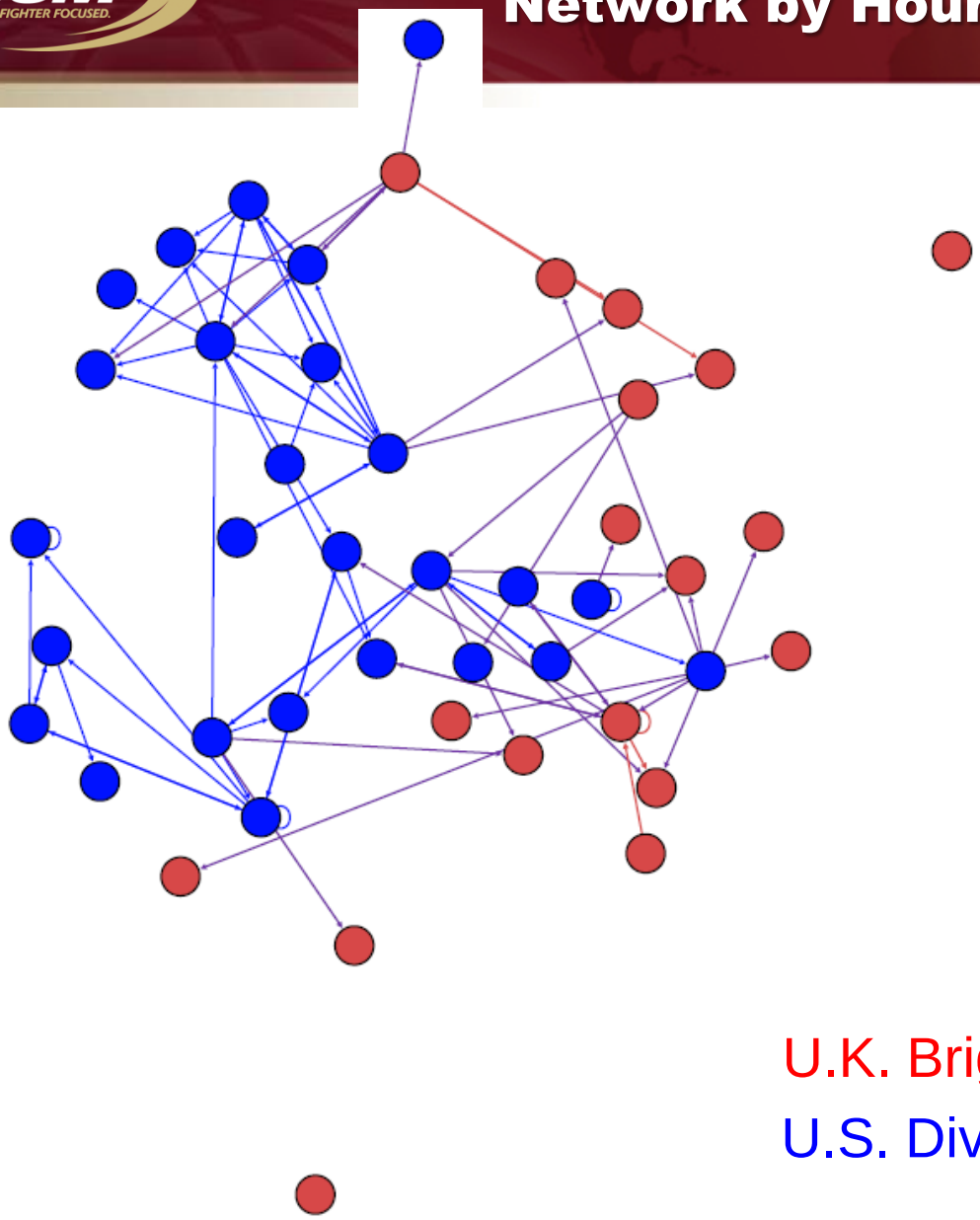


Hour 15

U.K. Brigade

U.S. Division

Network by Hour



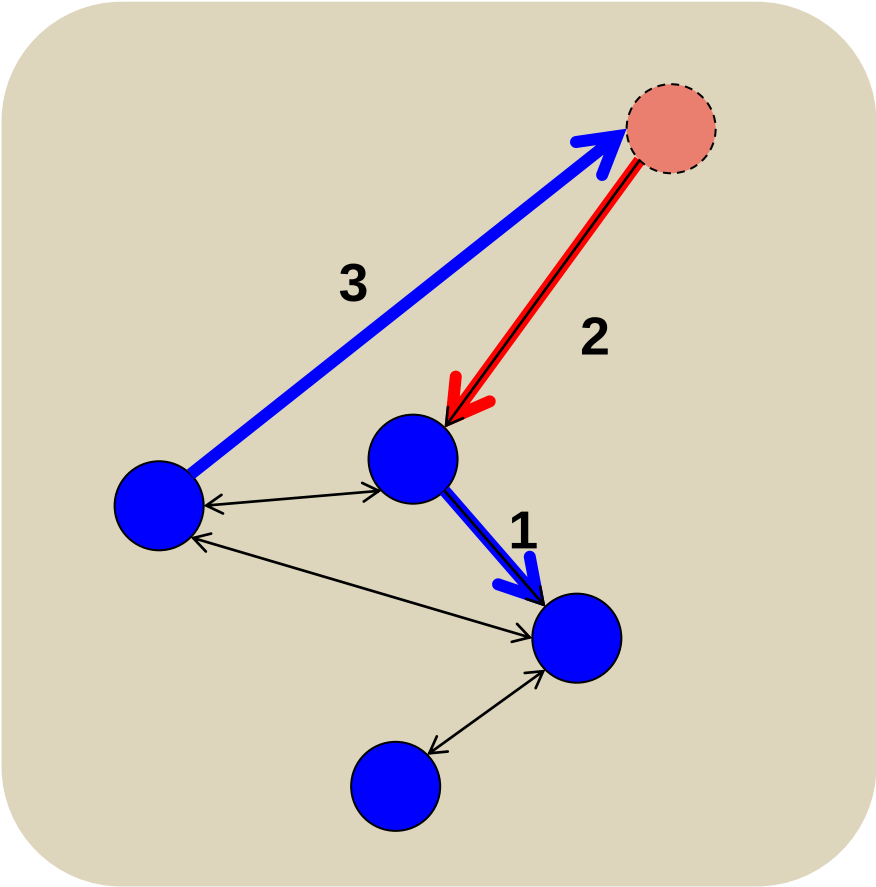
Hour 16

U.K. Brigade

U.S. Division

Link Types

- **Internal Links (1)**
  - e.g. Link from a division member to another division member
- **External Links IN (2)**
  - e.g. Link from member of a different group to a division member
- **External Links OUT (3)**
  - e.g. Link from division member to member of a different group



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Scenario Events

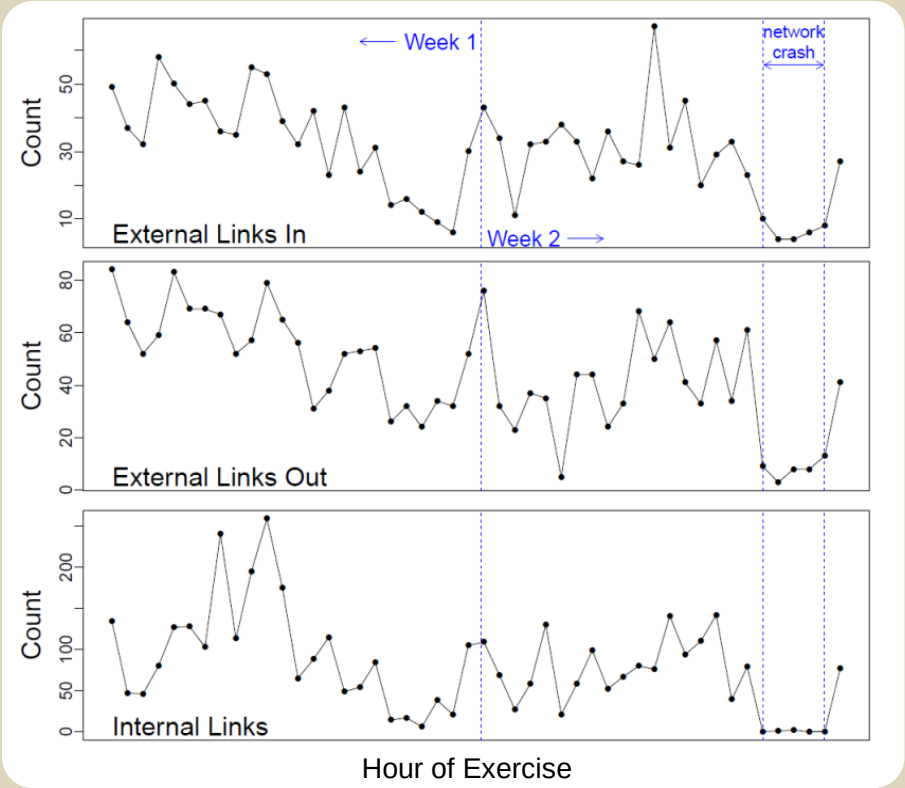
ARL

- **Training scenario generates overlapping series of event-driven tasks, requiring coordination among the C2 staff.**
- **Examples:**
  - Improvised explosive device (IED) in the area of operations
  - Civil demonstration
  - Intelligence report of enemy activity
- **Participants adhere to formalized military work routines and processes**
- **Events are time-sensitive and may have adverse cascading effects if not addressed in a timely manner.**
- **Participants construct specific, detailed material products (e.g. regular reports to the Commander from the staff)**

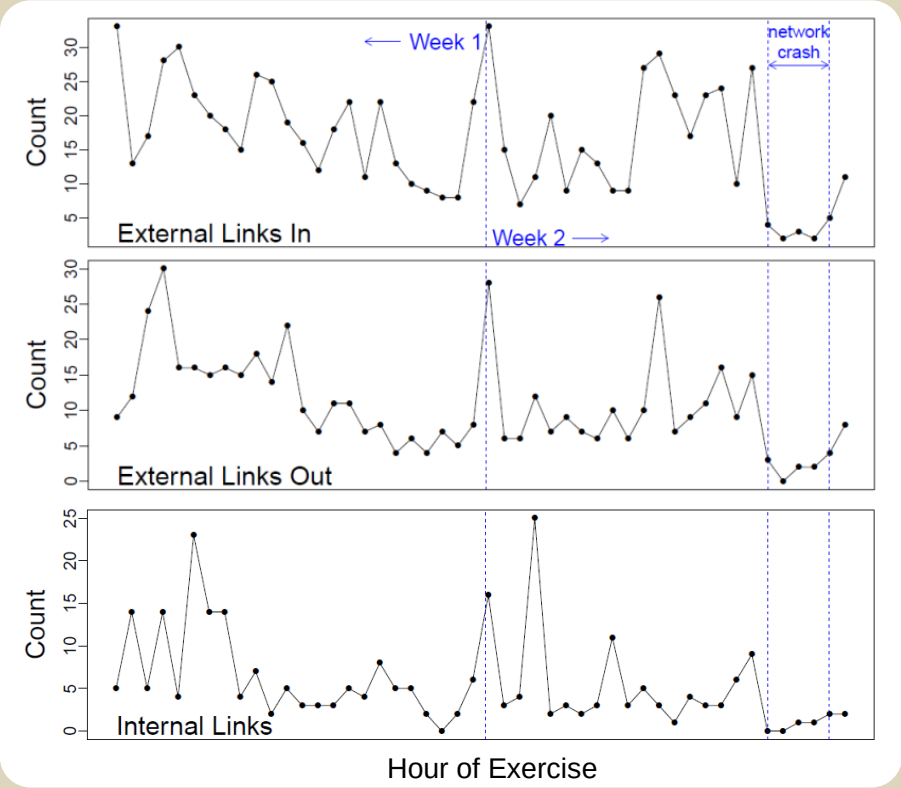
Time Series

Communications

Division

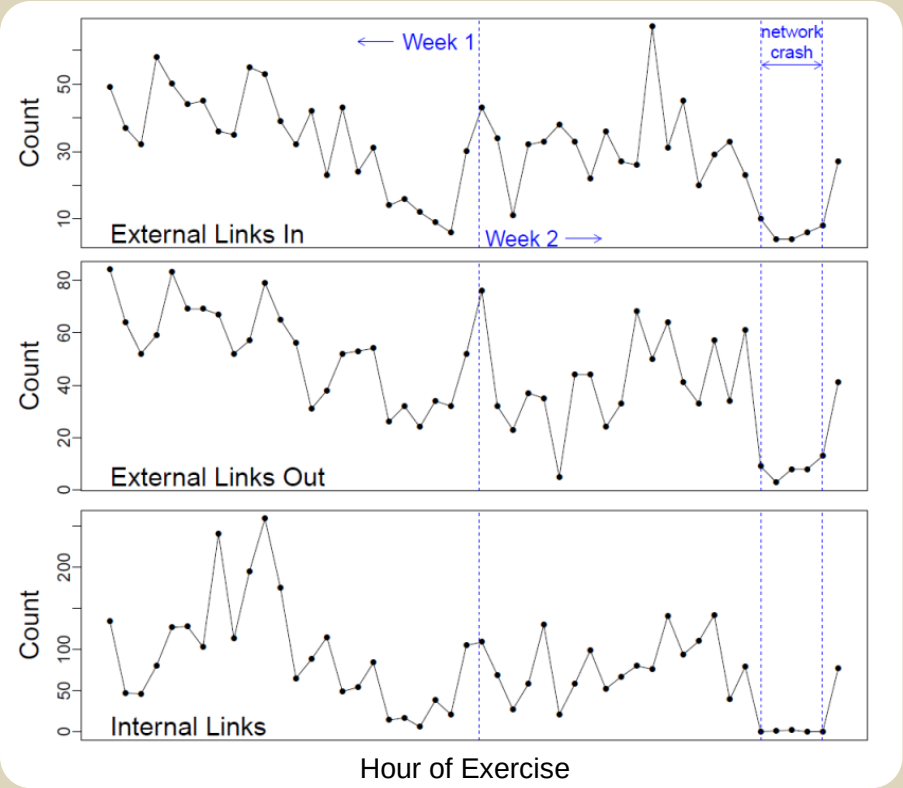


UK Brigade

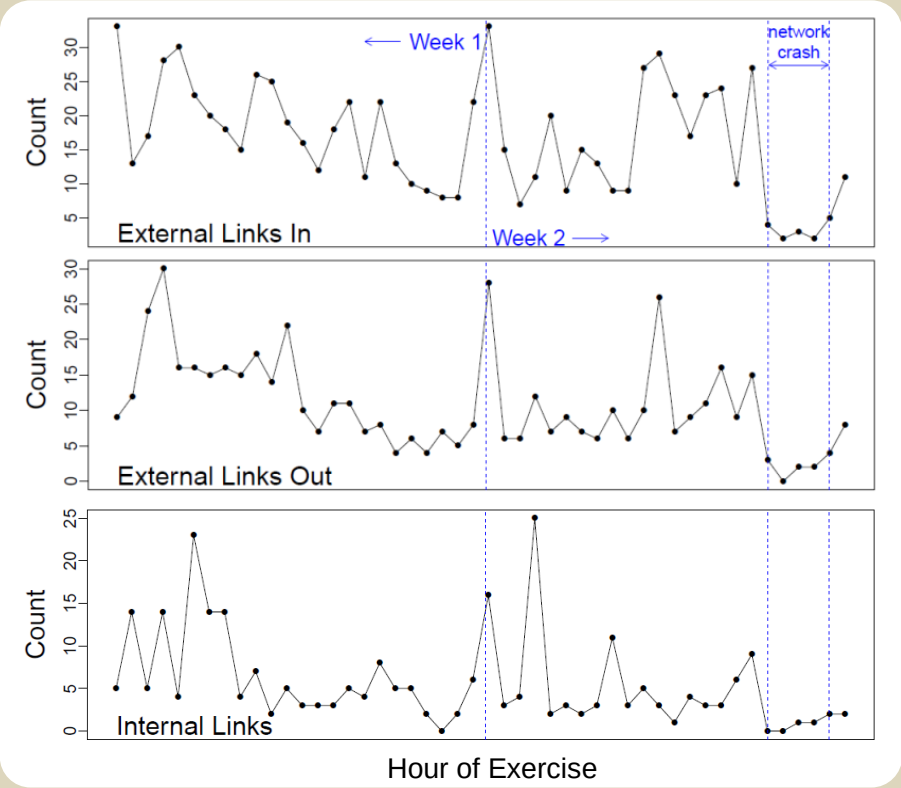


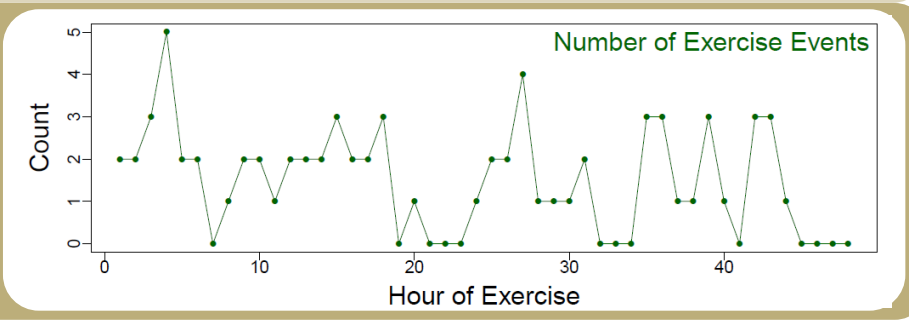
Time Series

Division



UK Brigade





Models

Division

Autoregressive Moving Average (ARMA) Model

- AR (1)

$$y_t = \alpha_0 + \alpha_1 y_{t-1}$$

- Predicts only on the basis of internal dynamics
- Only the immediately previous value of y is used to predict the current value

UK Brigade

Lag Dependent Variable (LDV) Model

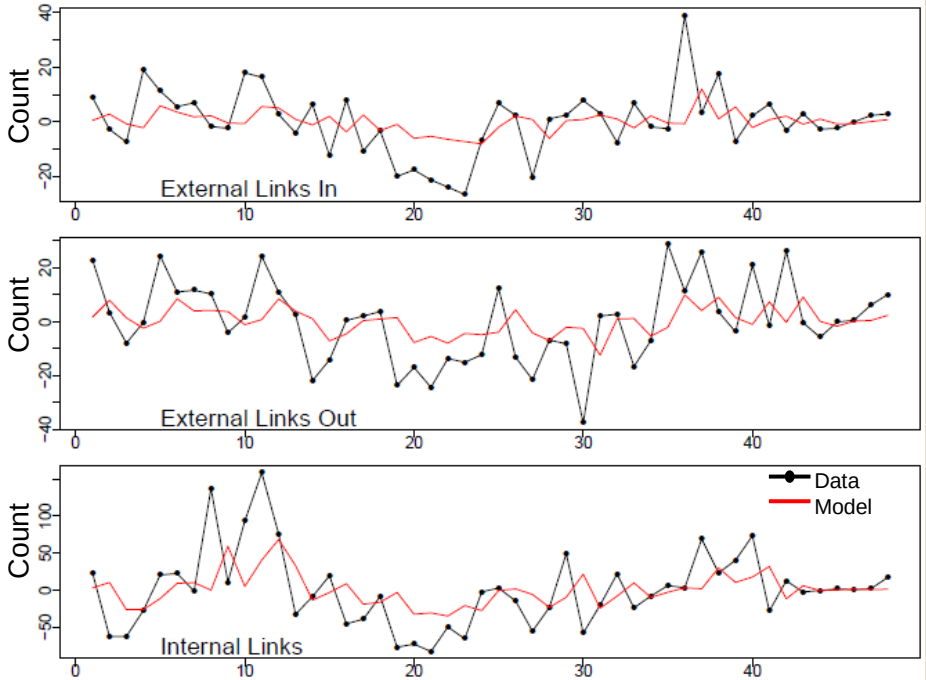
$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \beta x_t$$

- Predictors:
  - Current number of events - x
  - Previous value of y
- Predicts both long- and short-run effects of changes in the number of events

Model Predictions

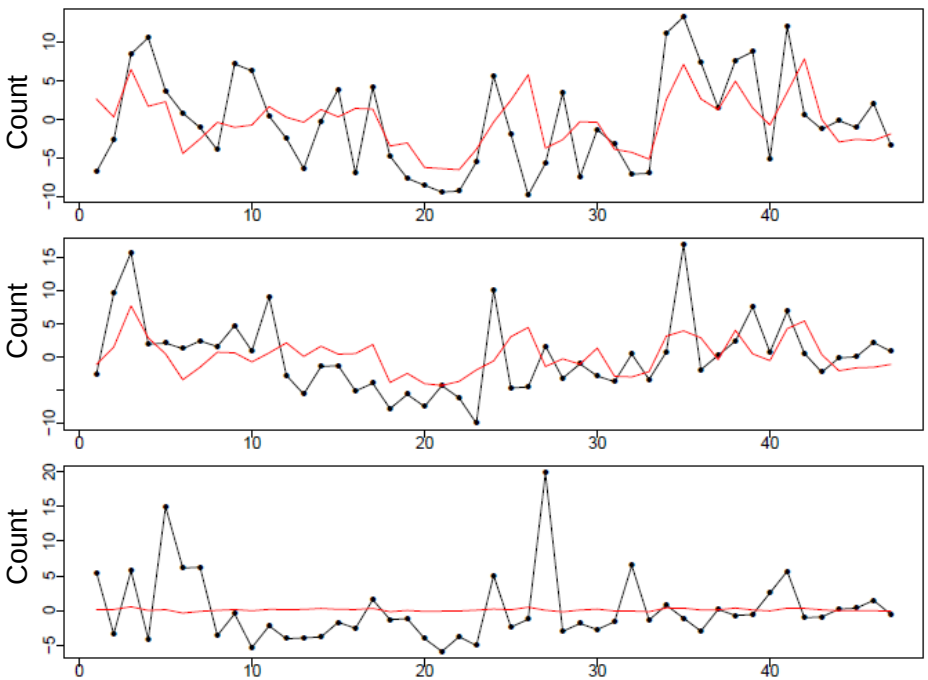
Division

ARMA Model



UK Brigade

LDV Model



Summary

- **Brigade communications best predicted by:**
  - Scenario events
  - Past communications
- **Division communications best predicted by:**
  - Past communications alone

Conclusions

- **Results suggest a correspondence between position in the hierarchy and sensitivity to external events**
  - Communication networks closer to the tactical edge exhibit a stronger response to external events.
- **Future work:**
  - Explore similar scenario-based data in even lower echelons (battalion, company, platoon…) to see if this relationship holds.
- **Application: Bandwidth usage and allocation.**
  - Relevant battlefield events are already currently recorded and tracked through significant activity reports (SIGACTs).
  - This SIGACT record could be used to make real-time predictions of communications volume.
  - Such predictions could in turn allow for more targeted dynamic bandwidth allocation.