Network Analysis

Of

US Health Departments

Riddhi Jain (UIN: 670543019)

Shubham Sharma (UIN: 675565126)

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Introduction

Abstract

Have you ever wondered who keeps an eye on your favorite restaurants to make sure your food is safe? Or acts when a hurricane strikes? In the US, these tasks are among the services provided by over 2,500 local health departments serving all communities across the country. In addition to basic services that keep us safe on a daily basis, local health departments also prepare for and respond to large-scale national, regional, and local emergencies.

Health department size and service provision vary widely depending on the needs and size of its constituent population, which can range from a few hundred to a few million people. Every few years, the National Association of County and City Health Officials (NACCHO) surveys health departments about their resources and the services they provide to constituents.

In 2016, the survey asked each health department to identify five health departments they connected to the most. Connections among health departments facilitate information sharing and coordination of services and are especially important during public health emergencies. The Ebola outbreak in 2014, Hurricane Harvey in 2017, and the California wildfires in 2018 are examples of national, regional, and state emergencies requiring coordination of public health services.

To understand the partnerships underlying the public health response to emergencies, let's examine the network of local health departments and identify key health departments and gaps in the network at the national, regional, and state level

Motivation

Our motivation to undertake this project is to answer the following questions:

(1) Is there a disparity between the medical resources available in the rural US and the urban US?

(2) Is there a way that the existing health networks can work together to reduce wastage of limited resources available and increase efficiency by reducing the time to respond to a local or national health emergency?

Objectives

With this project, we aim to understand the partnership that underlies the public health department's response to emergencies. We also aim to examine the network of local health departments and identify the key health departments. By understanding the above two objectives, we will be able to identify what are the strengths and weaknesses of the health department in the US- at national, regional and state levels. It will also highlight the key players and the gaps in the system.

We also tried to find the answers for some questions like:
Which health departments are most connected? Where are there gaps? What are the characteristics of central health departments?

Data Description

This Data is taken from 2016 survey by the National Association of County and City Health Officials (NACCHO). Of the 2533 LHDs (Local Health Departments) surveyed, 1930 (76%) responded to the 2016 Profile Study. One of the questions in the study elicited network data from LHDS by asking:
In thinking about your peers who lead other local health departments in the U.S., list the five LHDs whose leaders you communicate with most frequently about administrative, professional, and leadership issues in public health. In each instance, please provide only the LHD name rather than the leader's name.

After removing LHDs that did not respond to the network question, NACCHO had responses from 1387 LHDs to the network question. The 1387 LHDs identified a total of 5893 connections. We noticed that some connections were health departments connected to themselves or to a non-health department. We

removed these connections (n = 75) and we're left with a total of 1347 health departments in 48 states with 5818 connections among them.

Table 1: Dataset Variables

Variable	Meaning
naccho ID	The unique identifier for the LHD that answered the question
link.from	The name of the health department that answered the network question
link.to	The unique identifier for the partner identified by the respondent
state	The state the responding LHD is in
population	The size of the population the particular Health Dept is giving services to.
urban/rural	Whether it is a rural or urban setting.
fte	The number of Full-Time Employees.
leader.tenure	Number of years the leader of the health department is in service.

Data Cleaning

With more than 2,500 health departments in the US, the national network of partnerships may be large and complex. The first step in any analysis is to clean up the data. The health department network shows partnerships, which would logically be represented by a single link between any two health departments that partner. Local health departments do not typically partner with themselves, so there would be no loops in the network.

The project uses igraph and tidyverse commands (from readr and dplyr) to import and examine a network made up of an edgelist and an attribute file.

Statistics Summary - Nationwide Health Networks

After cleaning the data, the next step is some exploratory analysis to get to know the network.

No. of Vertices	2058
No. of Edges	5818
Network Density	0.00235

Table 2: Dataset summary Statistics

Connections facilitating coordination nationwide

In 2014, a case of Ebola was identified in Texas and health departments nationwide worked to prepare for the potential of a widespread outbreak. While this potential was never realized (there were just 4 cases eventually diagnosed in the US), it isn't difficult to imagine a large-scale infectious disease outbreak that requires coordination across the country to protect the uninfected and treat the infected.

Central network members can facilitate or control the spread of information and other resources and are often considered key or important network members. There are several different types of centrality. Two of the more commonly used are degree centrality and betweenness centrality. Degree centrality is a count of the number of connections a node has. Betweenness centrality quantifies the extent to which a node lies in the shortest path between any two other nodes in the network, often playing a bridging role.

The nodes with the highest degree and betweenness centrality may be key to spreading information and coordinating efforts nationwide. Nodes that have both high degree and high betweenness may be especially important.

Nodes with Highest Degree centrality

Node	Name of the Health Department
KY009	Clark County Health Department
NC060	Orange County Health Department
KY021	Jessamine County Health Department
OH066	Huron County Health District
OH092	Medina County Health District

Table 3: Nodes with highest Degree centrality

Nodes with Highest Betweenness centrality

Node	Name of the Health Department
WA022	N/A
MA043	Cambridge Public Health Department
MO049	Kansas City Health Department
TX144	Harris County Public Health & Environment Services
IN053	Marion County Public Health Department

Table 4: Nodes with highest betweenness centrality

Connections for Regional Coordination

Some disasters are more regional than national and would not require all health departments across the country to be involved. For example, in 2017, Hurricane Harvey poured between 10 and 50 inches of rain in a short period of time across parts of **southeastern Texas and southwestern Louisiana**. This resulted in widespread flooding across the region and tested the emergency preparedness of health departments and others. We used network methods to identify key players and gaps in the network across Texas and Louisiana that might suggest new connections to prepare for future events.

No. of Vertices	47
No. of Edges	105
Edges Density	0.0971

Identifying important nodes in each state using Degree Centrality

Louisiana	
Nodes	**Degree Centrality**
LA024	4
LA038	3
LA018	2
LA019	2
LA017	1

Texas	
Nodes	**Degree Centrality**
TX144	15
TX146	13
TX236	11
TX007	10
TX184	10

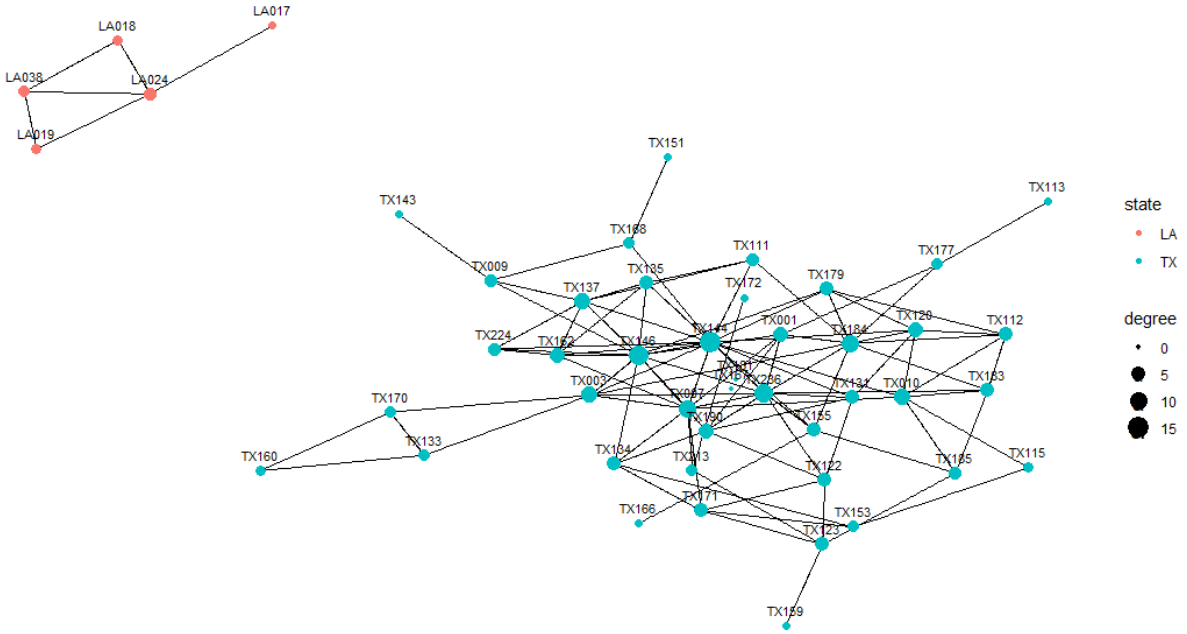
Identifying important nodes in each state using Betweenness Centrality

Louisiana	
Nodes	**Betweenness Centrality**
LA024	3.5
LA038	0.5
LA017	0.0
LA018	0.0
LA019	0.0

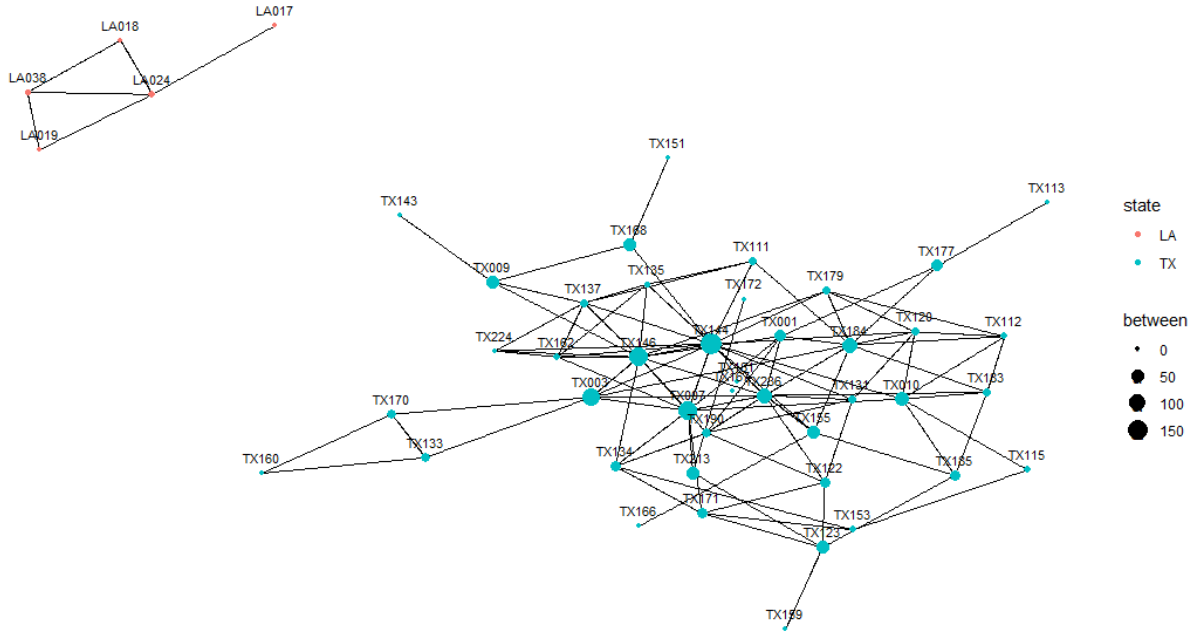
Texas	
Nodes	**Betweenness Centrality**
TX144	180.56815
TX007	137.29928
TX146	125.85243
TX003	111.81376
TX236	75.97649

Visualizing the Central Health Departments

Plotting with node size by degree, color by state, theme graph, Kamada Kawai layout



Plotting with node size by betweenness, color by state, theme graph, Kamada Kawai layout



Interpretation: The above graphs show that node TX 144 has both highest degree centrality and high betweenness centrality for Texas state. This shows that TX 144 is highly connected with other nodes as well as it is an important node acting as a bridge node in connecting other nodes. There can be many reasons behind this, like the population TX 144 giving its services to or the location advantage.

For Louisiana, node LA024 has the highest degree centrality and highest betweenness centrality, making it the most important node in the network.

Community Detection

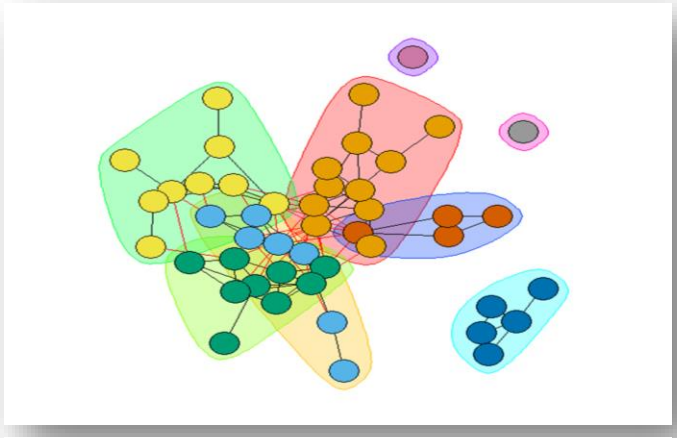


Image3: TX and LA communities

Interpretation: The community detection plot shows that there is no connection between Louisiana and Texas communities. Also, there exist 8 different communities in Texas Health department network. Out of these 8 communities 2 communities are not connected to any other community.

State Level Networks during Emergencies

There are national and regional emergencies like Ebola and Hurricane Harvey. There are also state and local emergencies like the wildfires in California in 2018. We tried to understand the network and its key players using the same approaches but with a single state network.

No. of Vertices	36
No. of Edges	67
Edges Density	0.1063

Finding the important nodes using Degree and Betweenness centralities.

Nodes	Degree Centrality
CA032	9
CA045	9
CA011	6
CA040	6
CA042	6

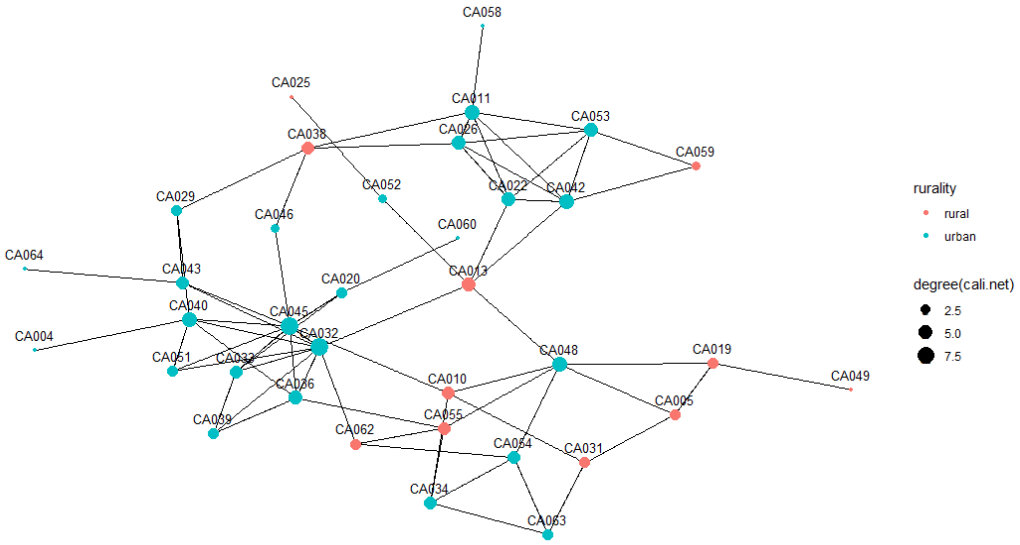
Nodes	Betweenness Centrality
CA013	217.63492
CA032	153.55476
CA048	147.99127
CA045	141.25476
CA010	10

Is the Central Health Department urban?

In addition to the state attribute, the network object includes several other health department characteristics that may be useful in understanding what makes two health departments partner with each other. One of the characteristics is rurality, which classifies each health department as rural or urban. Two other characteristics are fte, or full-time employees, and leader.tenure, which measures the years the leader has been at the health department.

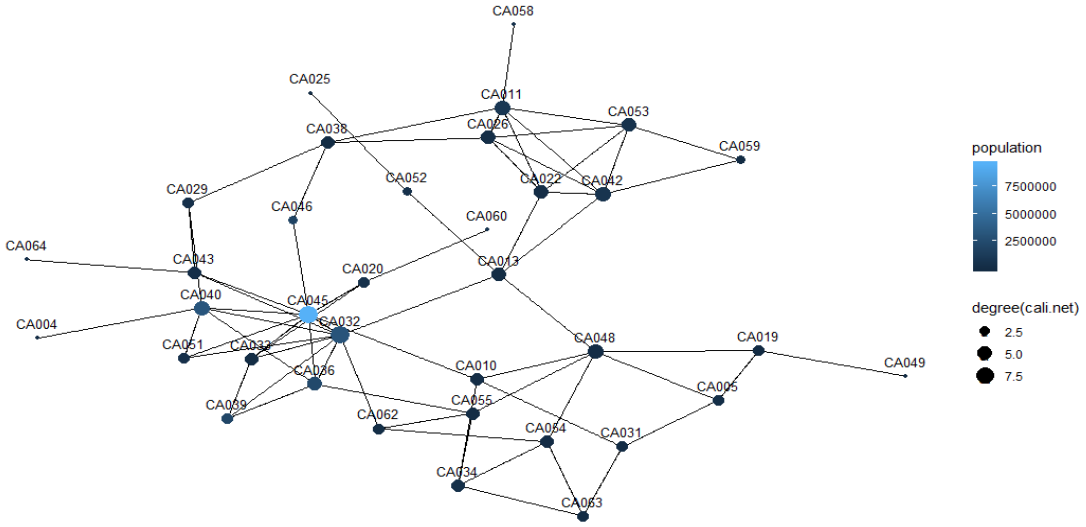
Urban health departments are likely to be in more populated areas and to serve more people. It would make sense that urban health departments are more central to the network since they have more resources to use in forming and maintaining partnerships. However, rural health departments might have more incentive to partner to fill gaps in service provision. Having more full-time employees and stable leadership could also influence the ability of health departments to partner.

Visualizing rurality in cali.net with `color` parameter with the rurality attribute and the `size` parameter with degree



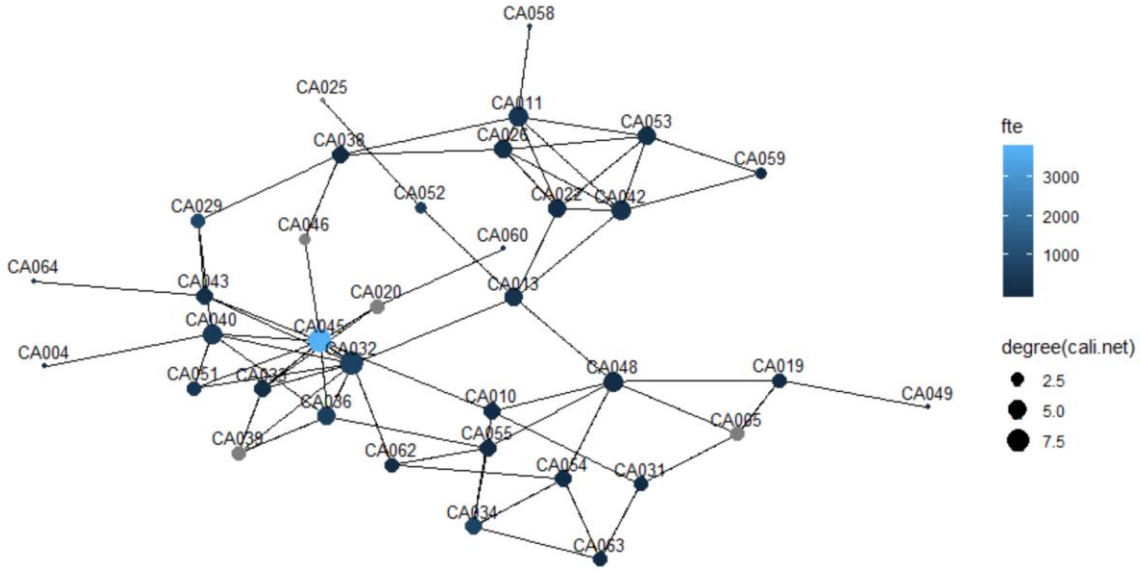
Interpretation: The above network graph shows that nodes CA032 and CA045 have high degree and betweenness centrality, thus can play an important role in health services across the state. Also, node CA013 has the highest betweenness centrality and is a rural health department that means it plays an important role is connecting other nodes.

Visualizing population in cali.net with `color` parameter with the population attribute and the `size` parameter with degree



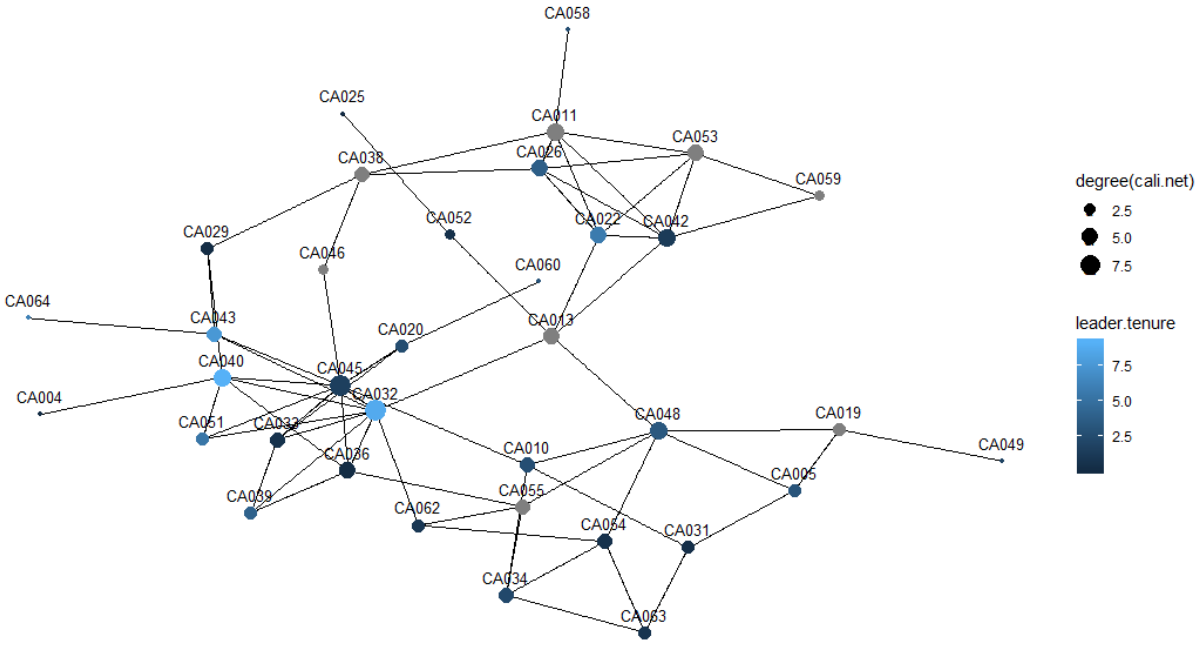
Interpretation: The above graph shows a relationship between degree centrality and population that health department is giving its services too. The degree of the node and the population it is serving too are directly proportional to each other. Node CA045 is serving to the highest population (highlighted with light blue color). CA045 is an urban health department and catering to a big population and hence has huge resource allocation. Maybe, that is the reason is it so well connected to other health departments and thus having high degree centrality.

Visualizing fte in cali.net the `color` parameter with the fte attribute and the `size` parameter with degree



Interpretation: The above network graph shows that there is a direct positive relationship between the number of full-time employees in a health department and the degree of that node. That means higher the number of full-time employees more is the probability that the health department is connected to other health departments. Node CA045 has the highest number of full-time employees and thus has very high degree. Though this assumption is not true for node CA032 which has high degree but do not have high number of full-time employees.

Visualizing leader.tenure in cali.net the `color` parameter with the leader.tenure attribute and the `size` parameter with degree



Interpretation: The above graph shows the relationship between the tenure of the leader of the health department with the connections that health department is having. Node032 and Node040 has leader with tenure of service thus having a high degree suggesting a direct positive relationship. However, this is not true for nodeCA045 which is highly connected, but the tenure of the leader is not that high.

Conclusion

After studying the health network structure of US at national, regional and state level, we concluded the following things-

Findings

From the regional US health network analysis, we can say the following things-

(1) The regional network of the state of Louisiana and Texas are highly disconnected even though they occasionally have similar regional disturbances.

(2) The health department in Texas have a high degree and betweenness centrality and are thereby the key players in coordinating the system.

(3) Only urban health departments were in the Louisiana network, which may indicate poor survey response by rural health departments, which often have extremely limited resources.

From the state US health network analysis, we can say the following things-

(1) In the state of California, we say that the most central node was CA013.

(2) The nodes with the highest level of connection were CA045 and CA032.

(3) Having more tenured and full-time employees is directly linked with stable leadership and higher level of connections between health departments.

Suggestions

- There is an opportunity for the health network in Texas and Louisiana to form new ties to improve coordination efforts in the future.
- The state of California can work on its ties between the rural and urban health departments.

Citation

https://www.nrhi.org/uploads/five-roles-rhics-play.pdf

References

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