Lecture 22 [the second ½]: Standards, protocols and regulations in Architecting Engineering Systems

ESD 342

May 2, 2006

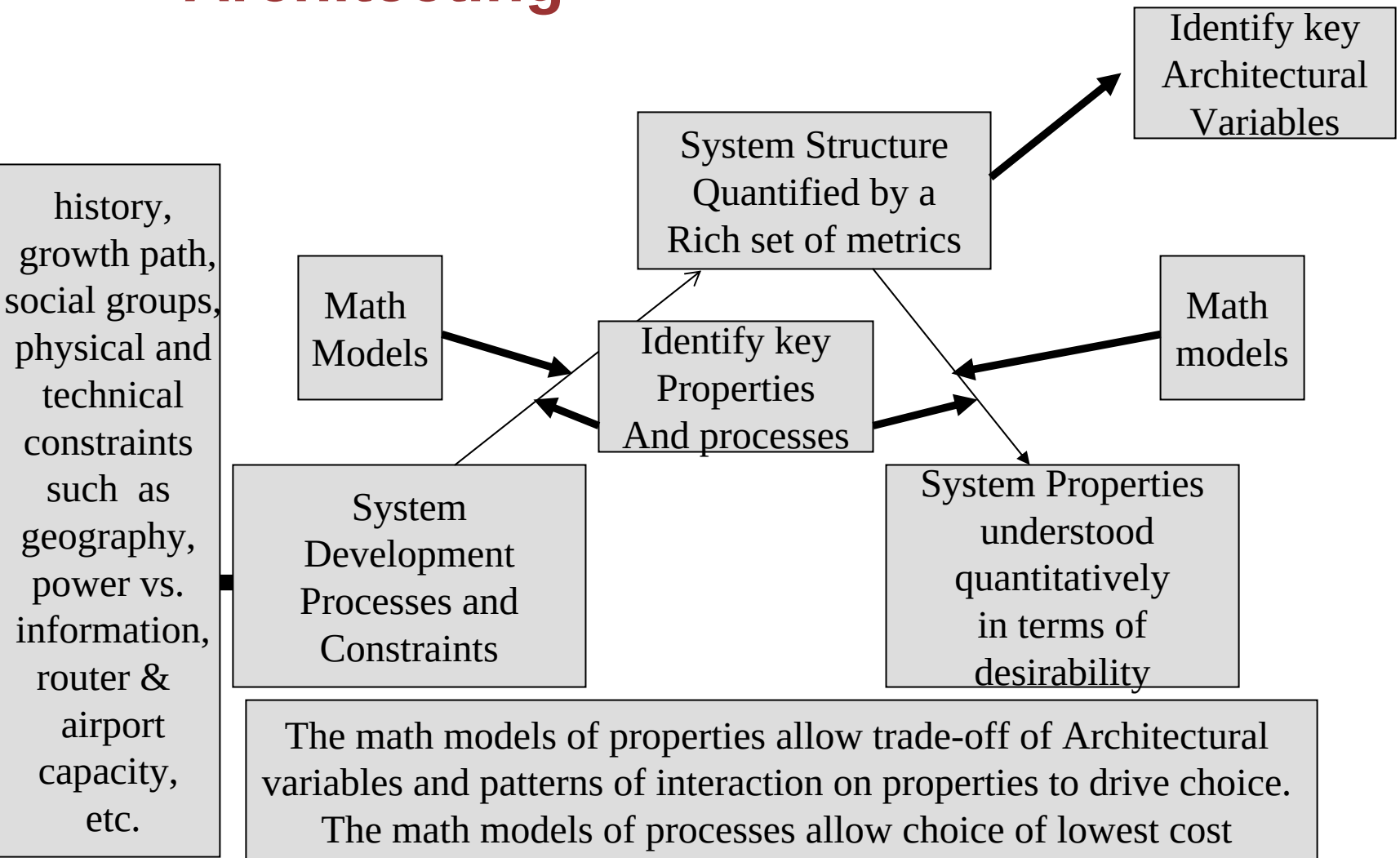
Learning Objectives

- Appreciate the critical role of standards in architecting engineering systems
- Understand the varying purposes and formation processes for standards as well as the interests of various academic disciplines in studying standards
- Explore some social and technical factors influencing standard formation
- Examine the Internet Standards as an interactive and evolving set of artifacts by using network analysis tools

Lecture Outline

- Introduction to role of standards in architecting engineering systems
- Standards Overview
  - Purposes
  - Modes of development
  - Academic interests in differing fields
- Historical Importance of standards in Engineering Systems
- Internet standards and network analysis (Mo-Han Hsieh thesis work)
  - Selected social network effects
  - Technical interdependency, communities and promotion

Schematic of Complex System Architecting



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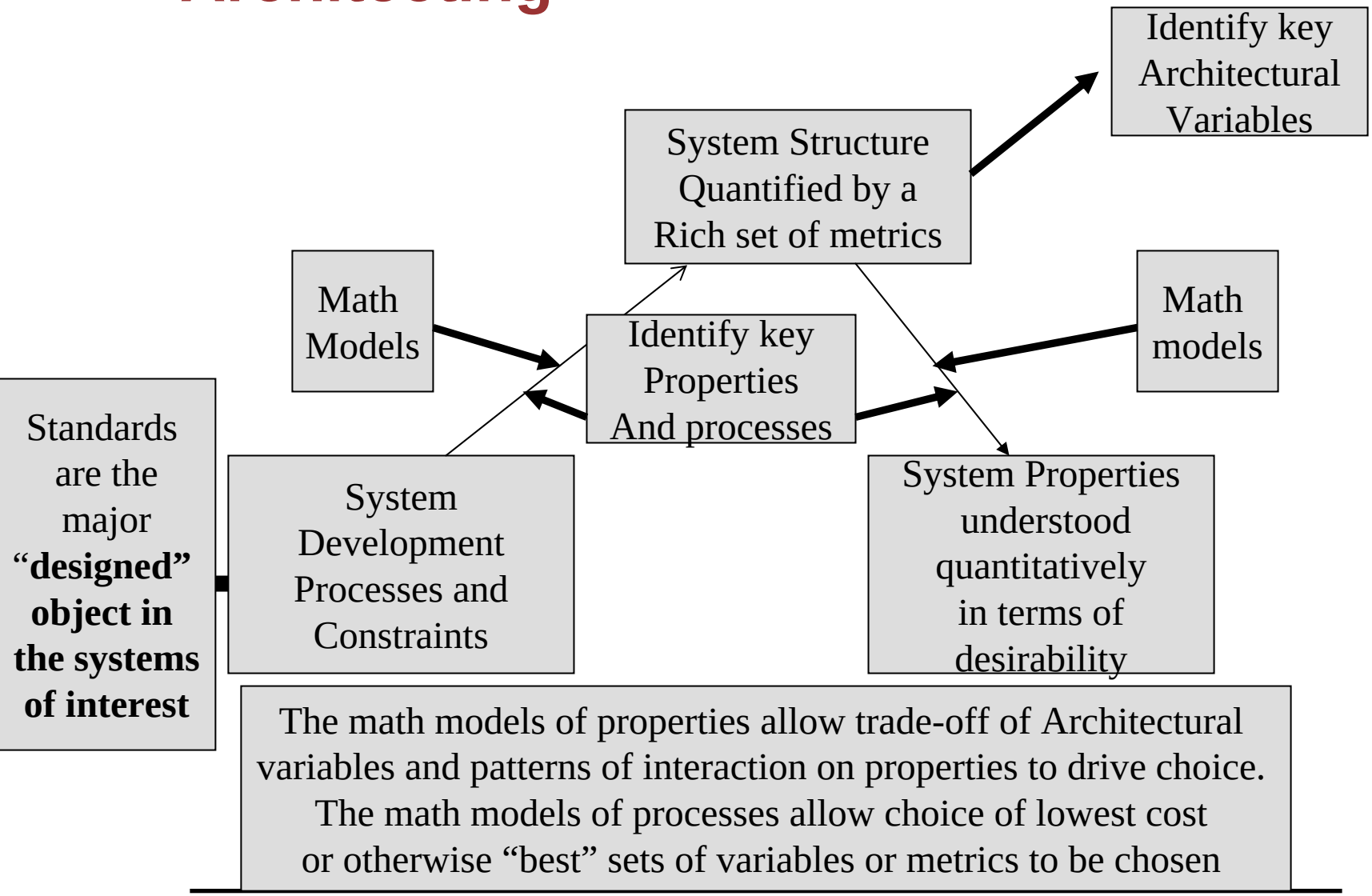

Definition of a Standard

- **Standard:** a set of **technical specifications** adhered to by *stakeholders over multiple instances*, either tacitly or as a result of a formal agreement (*modified* from David and Greenstein 1990).
  - **Explicit specifications** vs. norms, habits, customs, and other tacitly understood rules of practice.
- **Standardization:** the process by which explicit specifications for the form or function of a particular technology are created.
- ***Other terms used:***
  - *Protocols, agreements, conventions, treaties, etc. are used randomly / interchangeably for standards.*

Standards, Protocols and Regulation – Relationship to the Architecture of Systems

Are Standards relevant to modularity?

…Modularity 2

NSF Teragrid

Are Standards relevant to Flexibility?

Are Standards relevant to Robustness?

Standards are “difficult to change” and architecture is the long-lived part of design

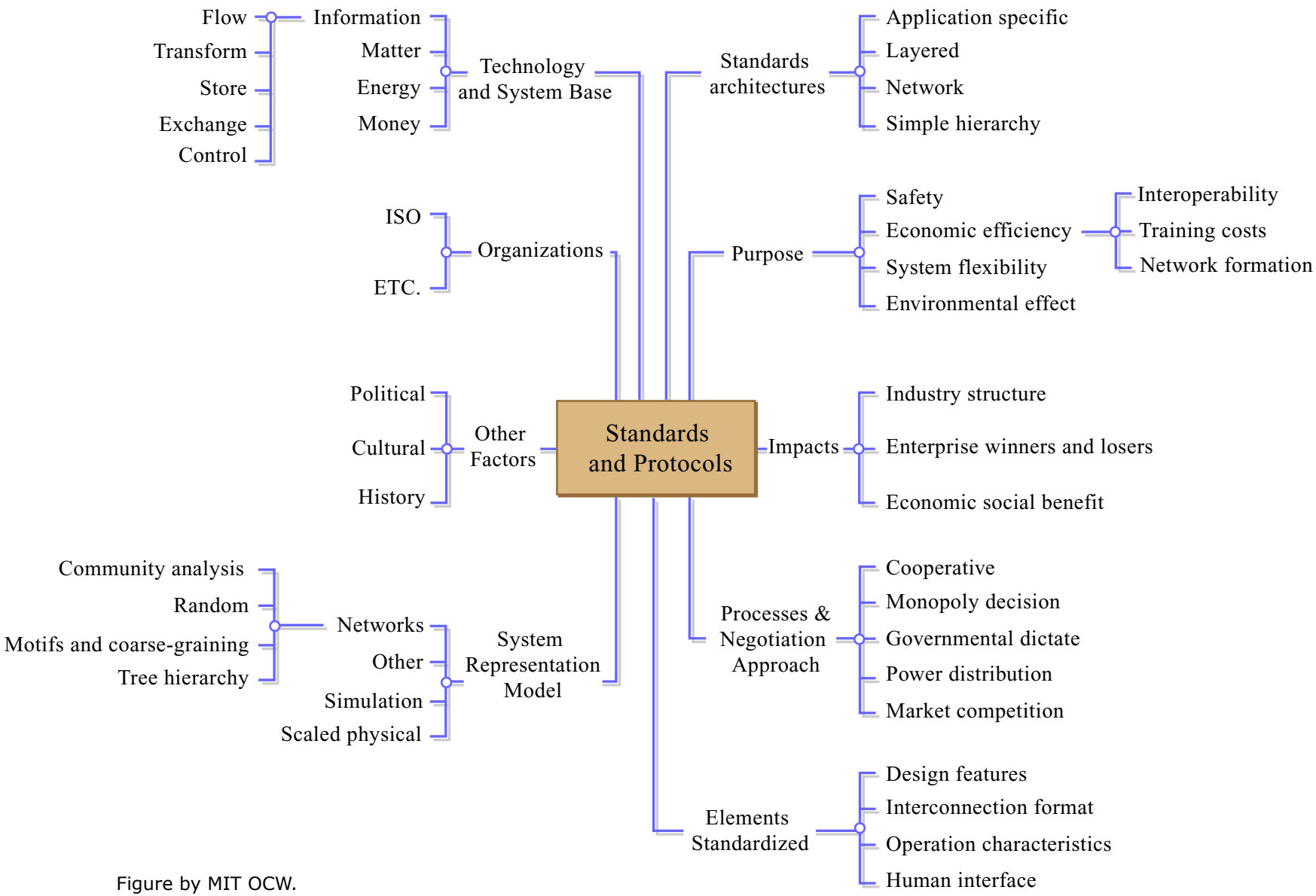

Figure by MIT OCW.

A Taxonomy of Standards

Purpose → Process ↓	Quality, Safety & Environment (specification of output results)	Compatibility & Interoperability (specification of internal design parameters)	Network connectivity (Interface specification)
Single Governmental Body (political)	1	2	3
Single Private Firm and market (competition)	4	5	6
Voluntary association of agents (cooperation)	7	8	9

Goals for Taxonomy

Collectively Exhaustive and Mutually Exclusive

Internally Homogeneous

Stability

Understandable Representation and Naming

Does our simple classification pass these tests?

As usual, the answer is ***no***

Processes are not mutually exclusive nor stable for a given standards area, purposes overlap as well…. *but it still appears useful*

Interests in standards in several (academic) fields

- Economics: The interaction of standards with "Industry Structure" is the major interest. The influence of competition and oligopoly on standards and the influence of industry structure on standard setting processes are the main foci.
- Sociology and history: The influence of social factors on standard development emphasizing detailed case studies.
- Political Science: The technical, political interaction process including regulatory capture and other phenomena that occur upon development of standards by governmental institutions
- Engineering: Participation in development of *specific* standards and assessment of the effectiveness of *specific* standards.

Categorization of standards and disciplinary interests

Purpose → / Process ↓	Quality, Safety & Environment (specification of output results)	Product interchange (specification of internal design parameters)	Network connectivity (Interface specification)
Single Governmental Body (Political)	1	2	3
Single Private Firm and market (competition) of firms	4	5	6
Voluntary association of agents (Cooperation)	7	8	9

Political Science focus

Economists' focus

Sociologists' focus

Largest complex system architecture effects

A Taxonomy of Standards

Purpose → Process ↓	Quality, Safety & Environment (specification of output results)	Compatibility & Interoperability (specification of internal design parameters)	Network connectivity (Interface specification)
Single Governmental Body (political)	1 Emissions Standards	2 NSA Encryption Standards	3 FCC Spectrum Control
Single Private Firm and market (competition)	4	5 VCR	6 Qwerty Keyboard
Voluntary association of agents (cooperation)	7 ISO 9000 Boiler codes	8 DVD HDTV	9 TCP/IP, WWW, JPEG, Electric power frequency

Examples of historically significant standards in area 9 in the taxonomy

- Meter, metric standards and time zone structure: governments as agents enabling world commerce growth (1st and 2nd IR)
- Railroad gage agreements: firms acting as agents to enable railroad growth (2nd IR)
- Electric power voltages, frequency and phases: firms as agents enabling electric power grid growth (2nd IR)
- Modern telecommunication standards: engineers and firms acting as agents to enable modern telecommunication networks such as the Internet and the world wide web to grow.(3rd IR)
- Standards such as JPEG: engineers and firms as agents acting to enable communication growth and quality.(3rd IR)
- Wireless standards such as GSM: firms and governments acting as agents to enable growth of wireless communication (3rd IR)
- Proliferation of open standards and corporate support

Open Standards: an IBM view

Linux

WAP

SOAP

WSDL

SMTP

POP/iMAP

TCP/IP

Globus

Web Services

NNTP

SQL

XML

IRC

OGSA

HTTP/HTML

Open Source Communities

Collaborative Innovation

- 10s of thousands of programmers worldwide

- Linux, Apache Web server, Eclipse, Open Grid Services Architecture . . .

Grid Computing

Accessing and Sharing Resources over the Internet, or Private Intranets, based on Open Protocols

Grid Computing

UK Research Grid

eDiamond Project
Oxford University

NSF Teragrid

Dutch National Grid

National Digital
Mammography
Archive

Istituto Nazionale di
Fisica Nucleare

Butterfly.net

Examples of standards in area 9 in the taxonomy-note Growth importance

- Meter, metric standards and time zone structure: governments as agents enabling world commerce **growth** (1st and 2nd IR)
- Railroad gage agreements: firms acting as agents to enable railroad **growth** (2nd IR)
- Electric power voltages, frequency and phases: firms as agents enabling electric power grid **growth** (2nd IR)
- Modern telecommunication standards: engineers and firms acting as agents to enable modern telecommunication networks such as the Internet and the world wide web to **grow**.(3rd IR)
- Standards such as JPEG: engineers and firms as agents acting to enable communication **growth** and quality.(3rd IR)
- Wireless standards such as GSM: firms and governments acting as agents to enable **growth** of wireless communication (3rd IR)
- How important is **growth** in enabling the cooperative process?

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Standards, Protocols and Regulation – Technical and Social Aspects/Architecture of standard system

- Technical and Social Aspects
  - What technical factors affect the development of protocols and standards?
  - What social factors affect the development of protocols and standards?
  - Can they be considered separately?

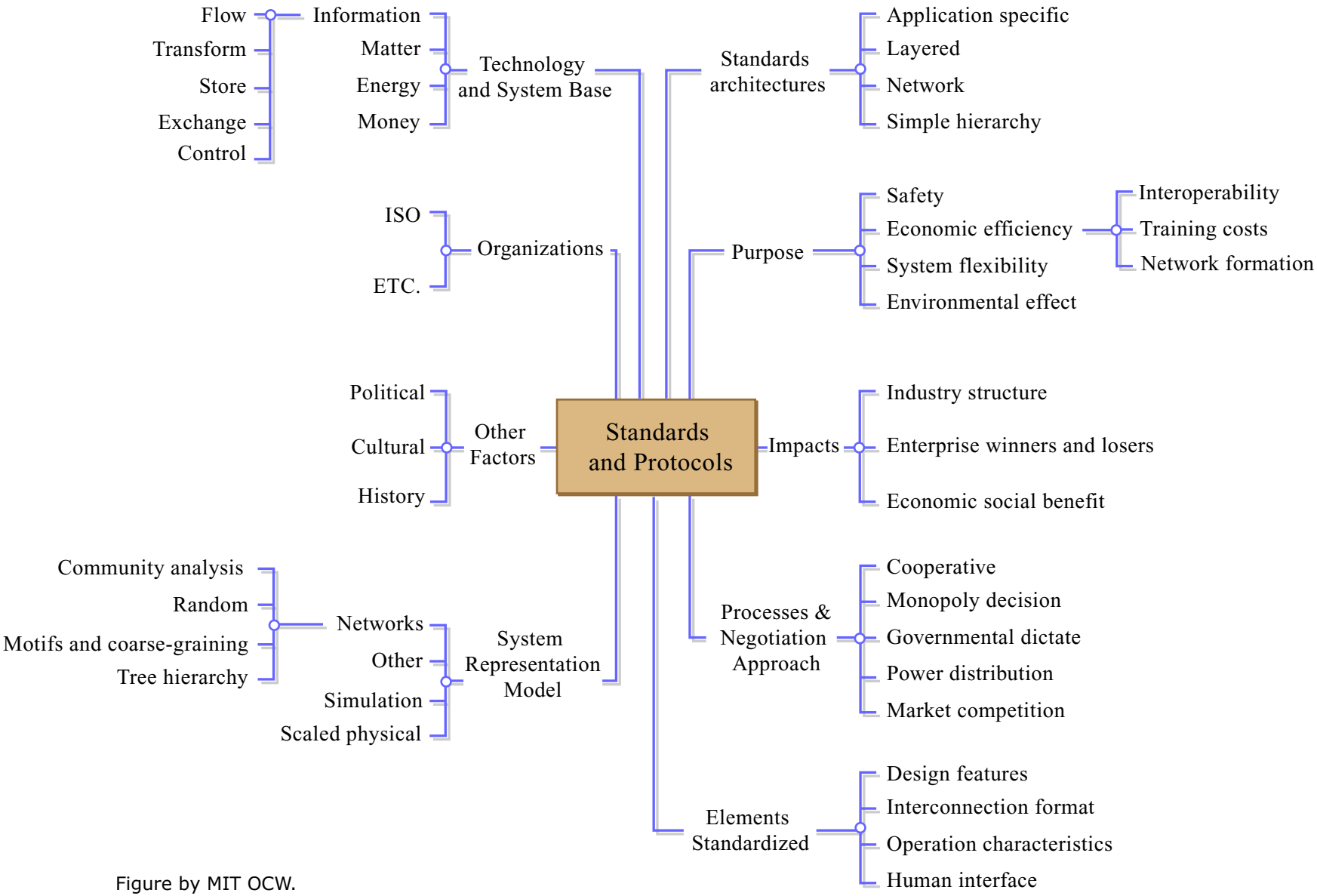


Figure by MIT OCW.

How can we simultaneously consider the technical and social factors?

Standards, Protocols and Regulation – Technical and Social Aspects/Architecture of standard system

- Technical and Social Aspects
  - What technical factors affect the development of protocols and standards?
  - What social factors affect the development of protocols and standards?
  - Can they be considered separately?
- Architecture of standards and their relationship to system architecture
- Recall Quote from Evo Devo Book..

Animal architecture is a product of genetic regulatory network architecture." (from S. Carroll P 129 italics added)

Perhaps.. *System architecture is a product of the standards network architecture that regulates that system*

And *System evolvability (one aspect of flexibility) is a product of the fundamental character of the standards architecture regulating the system*

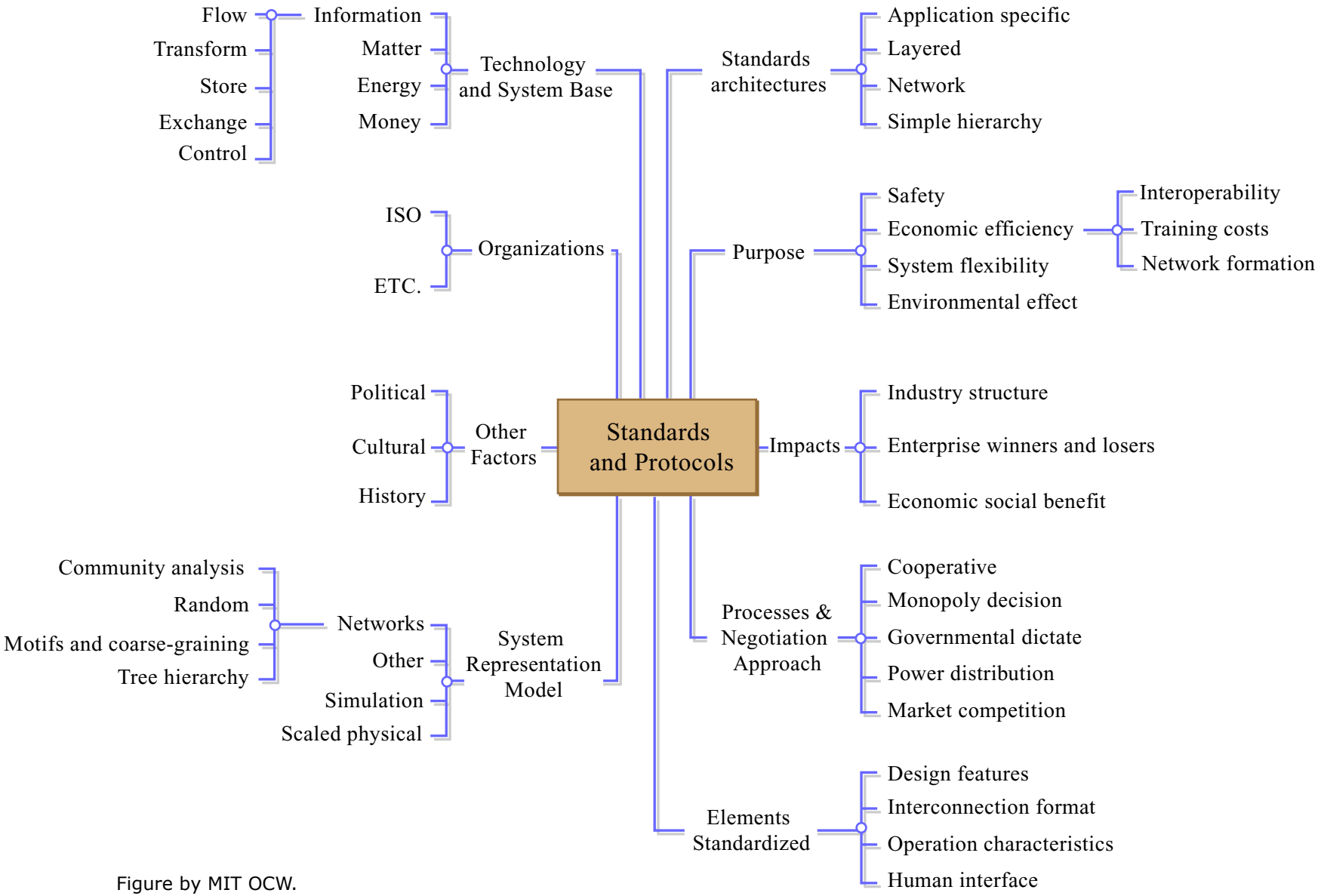


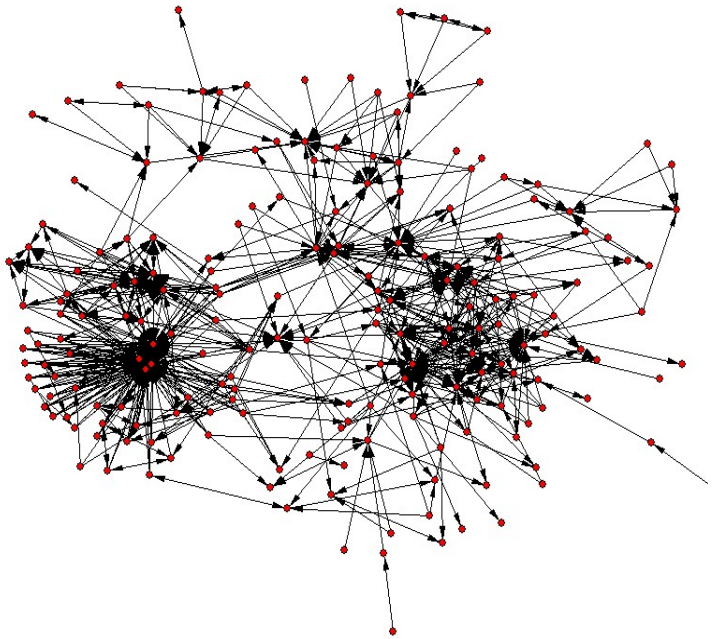
Figure by MIT OCW.

What can we learn about standards architecture and its relationship to system architecture?

Potential Data Sources: Citation networks and social (co-author networks, e-mail)

Data Source	Assessment		
	Avail. Standards	Time Series Data	Archival Data
IETF	**1,000** **75 Internet Std.** **75 draft Std.** **850 proposed Std.**	**1969 – 2005** **(About 4,000 RFCs)**	**Email archive of every ever existing working group**
W3C	250 80 recommendations 20 candidate rec. 30 working draft in last call 120 working draft in dev.	1994 – 2005 (Including revision histories)	1. Working group meeting minutes 2. Group Notes of every working group
ASTM	12,000	1970 – 2004	n/a
SAE	1,900	1918 – 2004	n/a
ISO	15,000	Not available (n/a)	n/a
ITU	2,900	n/a	n/a
ECMA	230	n/a	n/a

IETF Standards Network

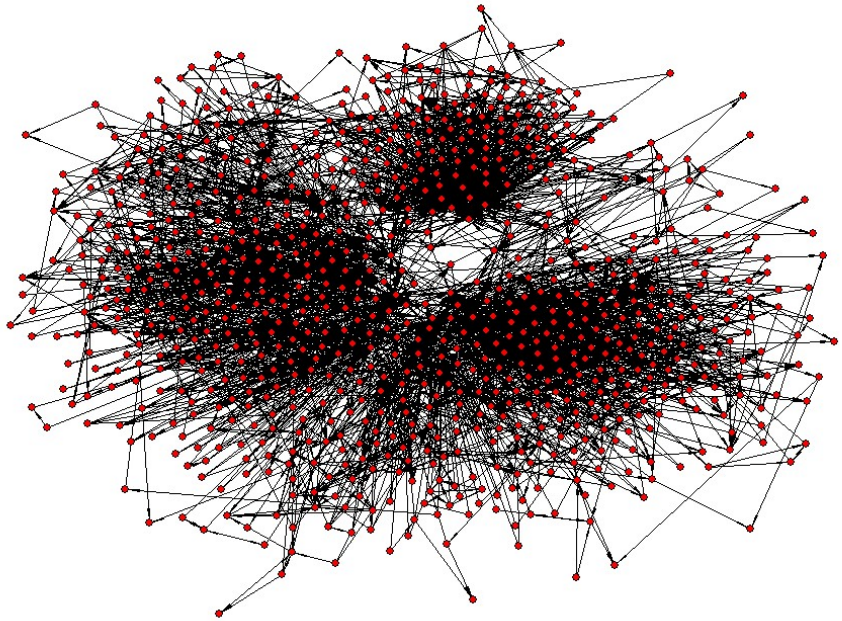


Year: 1994

N=206

# of arcs: 752

Density: 0.0178



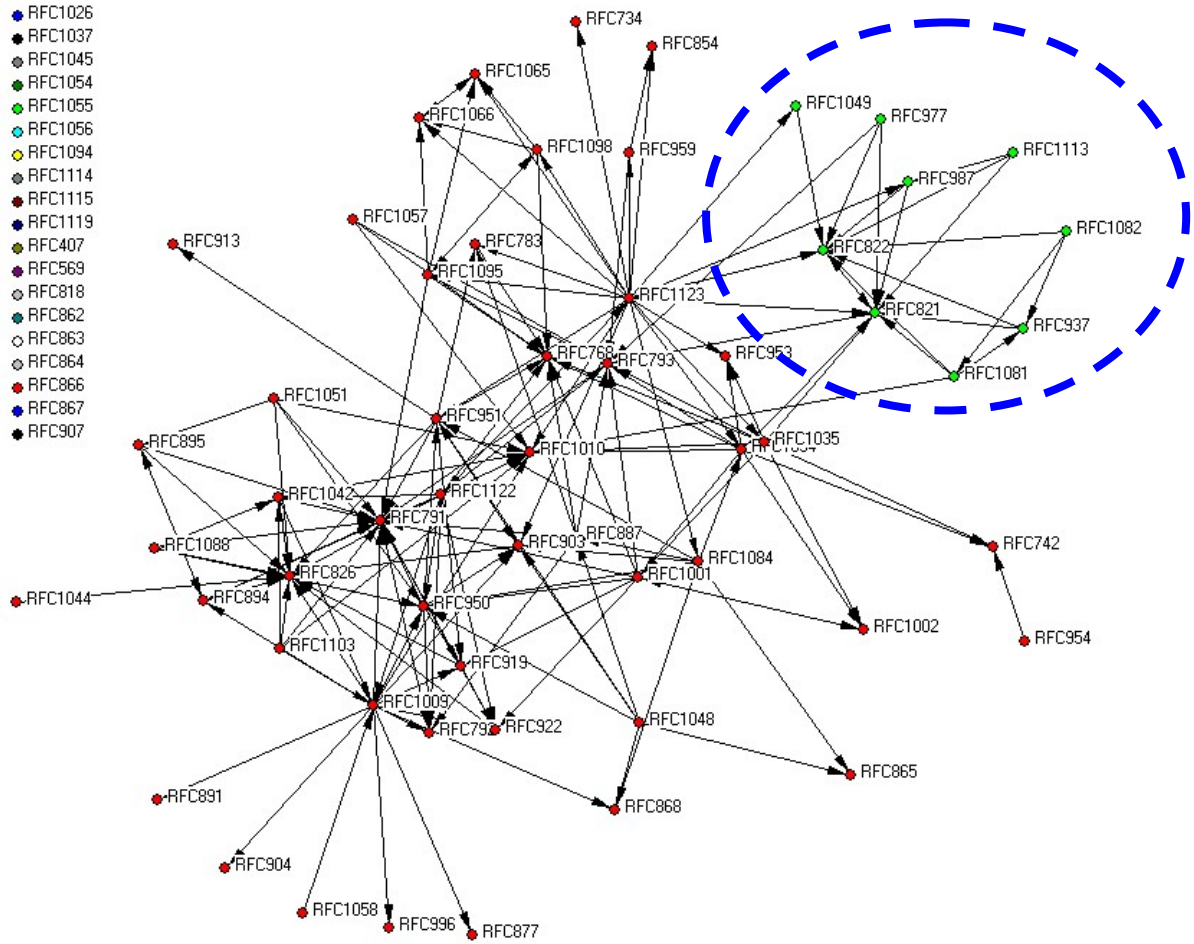
Year: 2004

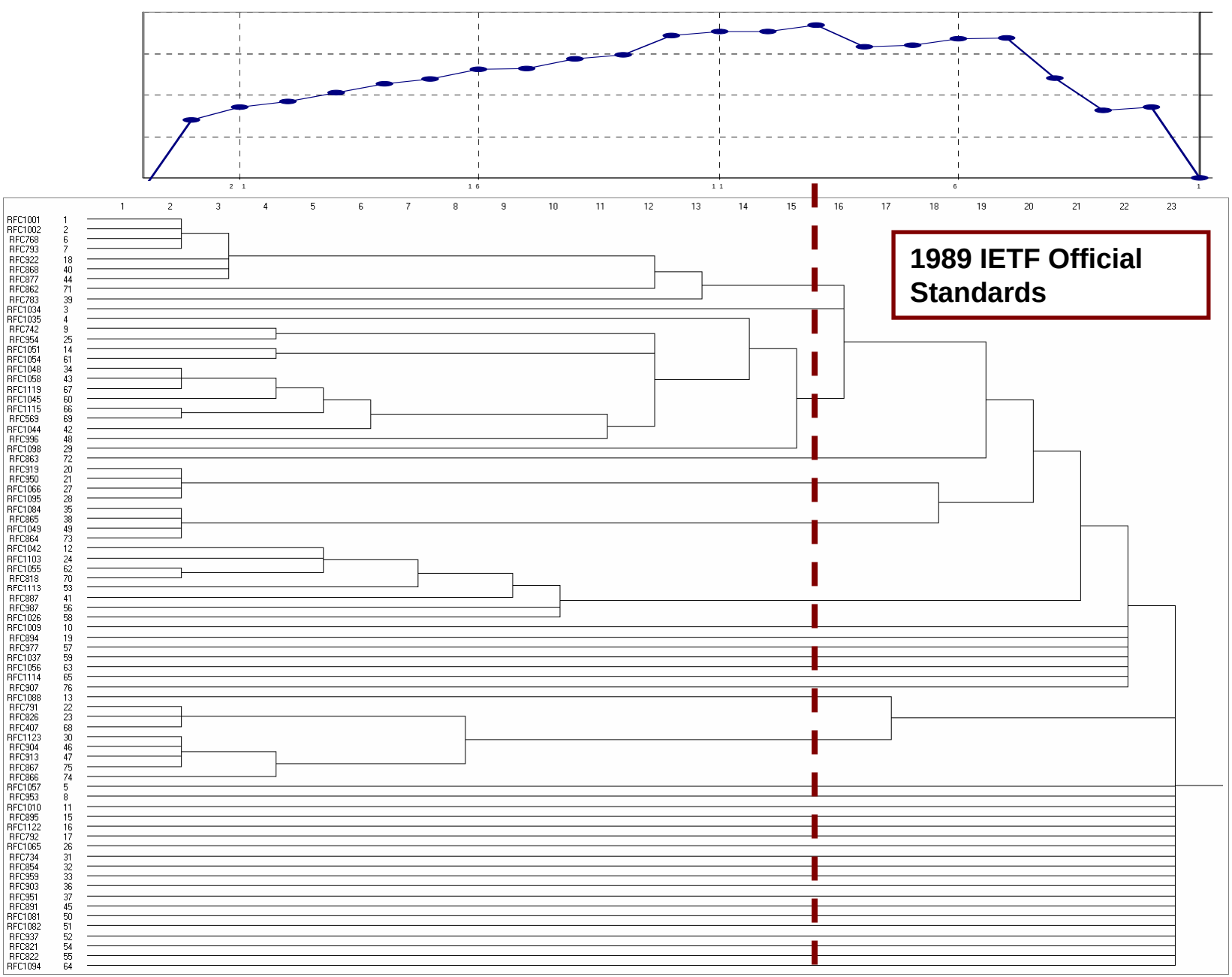
N=998

# of arcs: 4418

Density: 0.0044

Newman-Girvan Algorithm – First Separation of the Main Component for IETF 1989 Standards:

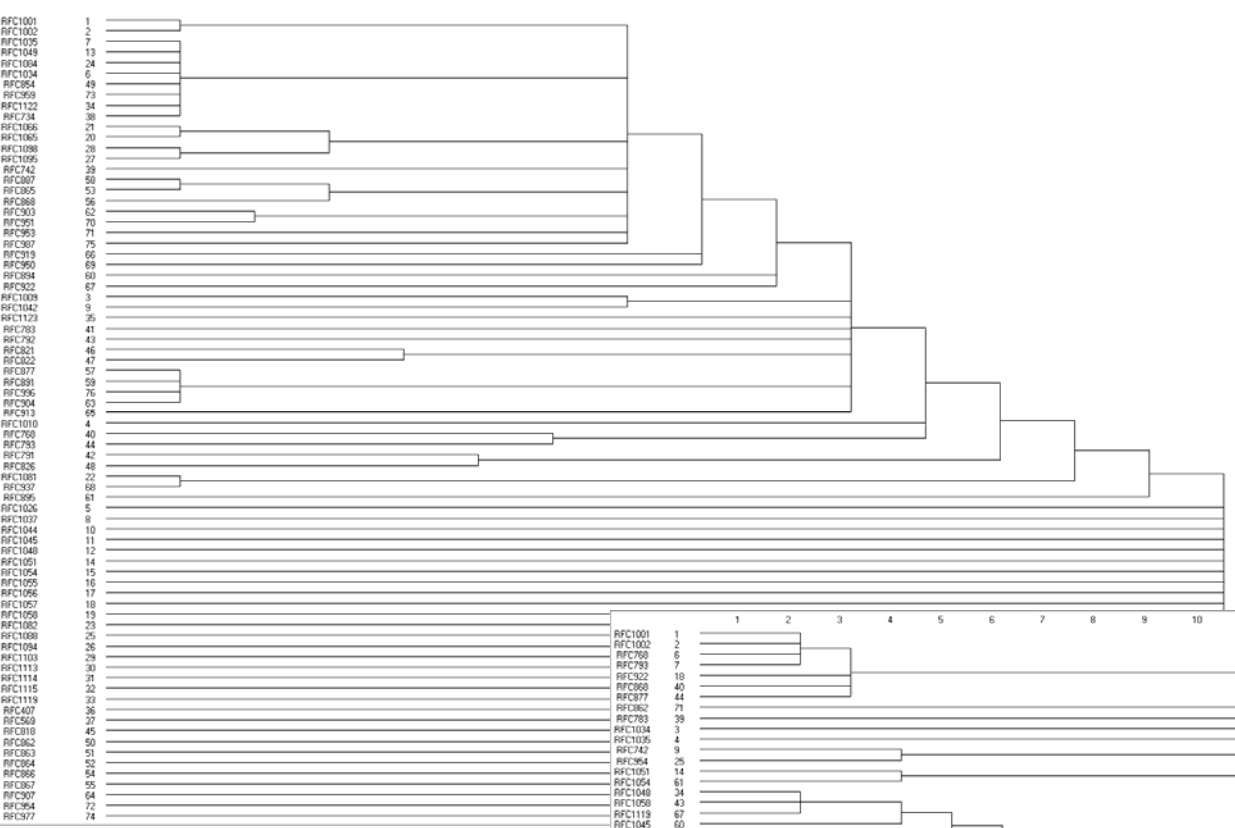



0 . 4
0 . 3
0 . 2
0 . 1
0 . 0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
RFC1001 1
RFC1002 2
RFC768 6
RFC793 7
RFC922 18
RFC868 40
RFC877 44
RFC862 71
RFC783 39
RFC1034 3
RFC1035 4
RFC742 9
RFC954 25
RFC1051 14
RFC1054 61
RFC1048 34
RFC1058 43
RFC1119 67
RFC1045 60
RFC1115 66
RFC569 69
RFC1044 42
RFC996 48
RFC1098 29
RFC863 72
RFC919 20
RFC950 21
RFC1066 27
RFC1095 28
RFC1084 35
RFC865 38
RFC1049 49
RFC864 73
RFC1042 12
RFC1103 24
RFC1055 62
RFC818 70
RFC1113 53
RFC887 41
RFC987 56
RFC1026 58
RFC1009 10
RFC894 19
RFC977 57
RFC1037 59
RFC1056 63
RFC1114 65
RFC907 76
RFC1088 13
RFC791 22
RFC826 23
RFC407 68
RFC1123 30
RFC904 46
RFC913 47
RFC867 75
RFC866 74
RFC1057 5
RFC953 8
RFC1010 11
RFC895 15
RFC1122 16
RFC792 17
RFC1065 26
RFC734 31
RFC854 32
RFC959 33
RFC903 36
RFC951 37
RFC891 45
RFC1081 50
RFC1082 51
RFC937 52
RFC821 54
RFC822 55
RFC1094 64
1989 IETF Official Standards

Co-citation Strength

- **Co-citation strength**
  - The number of documents that have cited a given pair of documents
  - Reversal of Kessler's bibliographic coupling concept, which uses the number of references a given pair of documents have in common to measure the similarity of their subject matter.

Hierarchical Clustering of Co-citation Strength (1989 IETF Official Standards)



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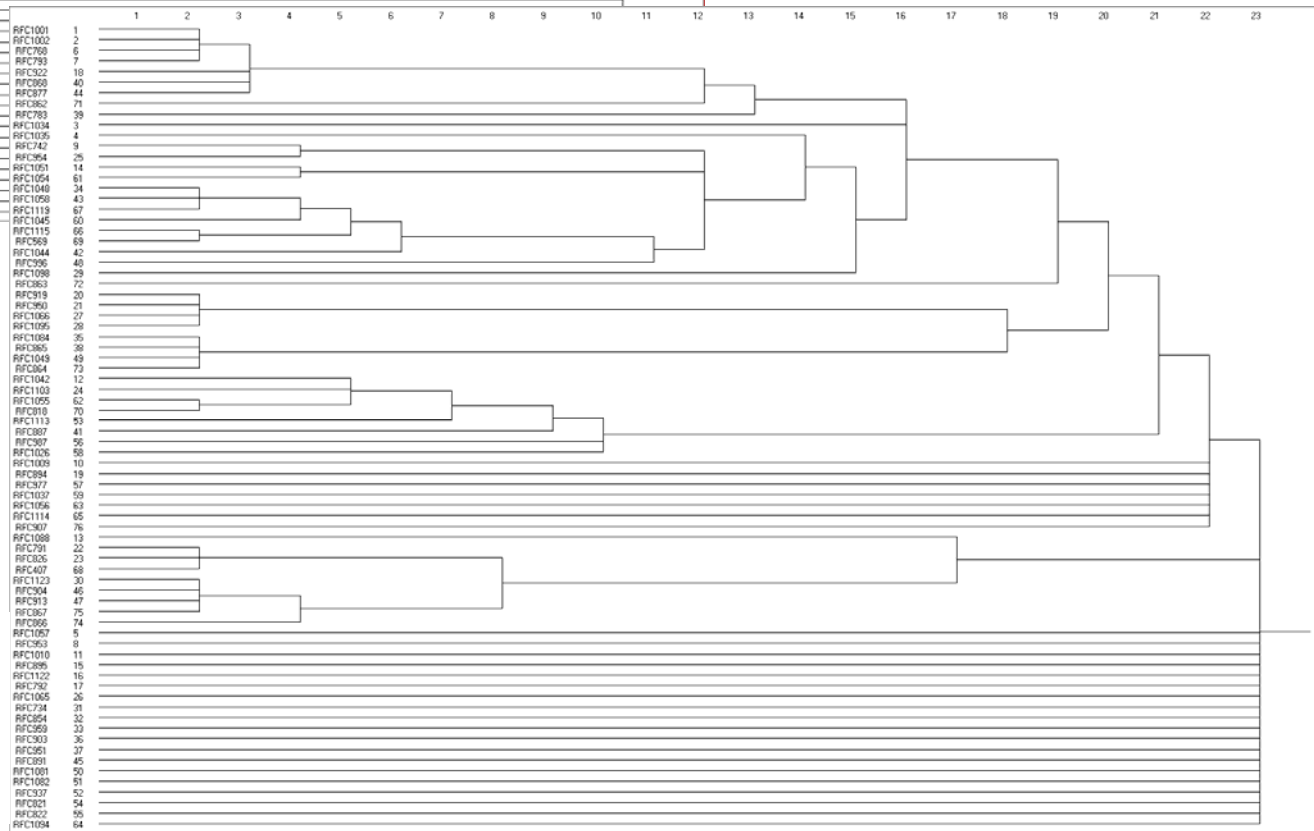


Community Analysis of Internet Standards; Conclusions

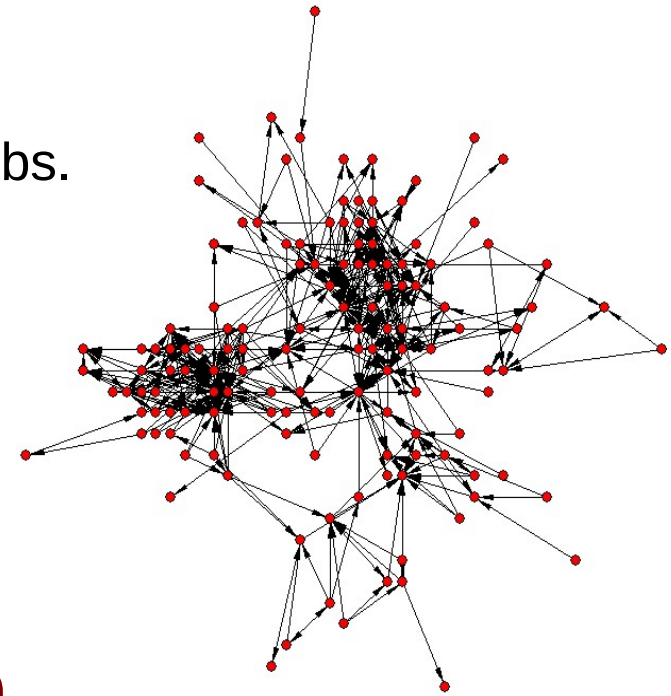
- The observed communities of standards appear appropriate- that is the “experimentally determined” communities largely align by IETF working groups and by the layer subdivision that is the working mental model for understanding the standards architecture.
- Time series studies allow one to observe the emergence of new communities
- Although more elaborate separation methods improve the resolution of separate communities, they are sill quite interdependent (cross-citation is common); moreover, it appears the Internet Architecture is (not surprisingly) much more difficult to change now than in the past.
- The possible practical significance of these observations are currently being investigated.

Time Series Promotion of Standards

Multidimensional scaling of path distance on IETF official standards (1994)

Authority: not only referred to by many nodes, but also by many Hubs. (measurement: ***prestige***)

Hub: not only refers to many nodes, but also to many Authorities. (measurement: ***acquaintance***)



A : adjacency matrix
x_i : prestige (of node i)
y_i : acquaintance

$$Ax = \lambda y$$
$$A^T y = \mu x$$

Solve for x and y.

Promotion Study in IETF Standards (II)

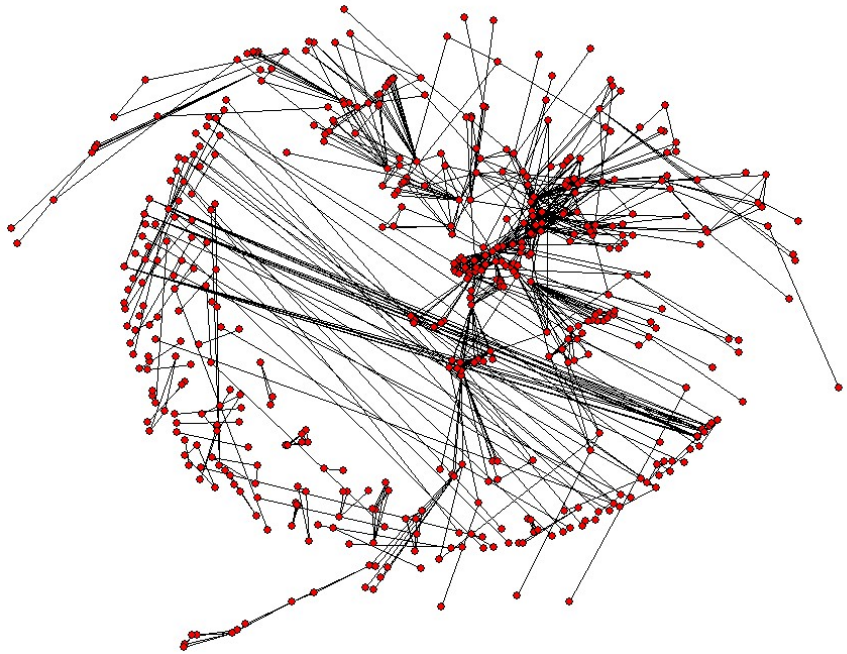
Coauthor network of the RFC authors.

Two types of centrality:

Degree centrality

$$C_D(n_i) = d(n_i) = x_{i+} = \sum_j x_{ij} = \sum_j x_{ji}$$

$$C'_D(n_i) = \frac{d(n_i)}{g-1}$$



Betweenness centrality

$$C_B(n_i) = \sum_{j<k} g_{jk}(n_i)/g_{jk}$$

$$C'_B(n_i) = C_B(n_i)/\left[(g-1)(g-2)/2\right]$$

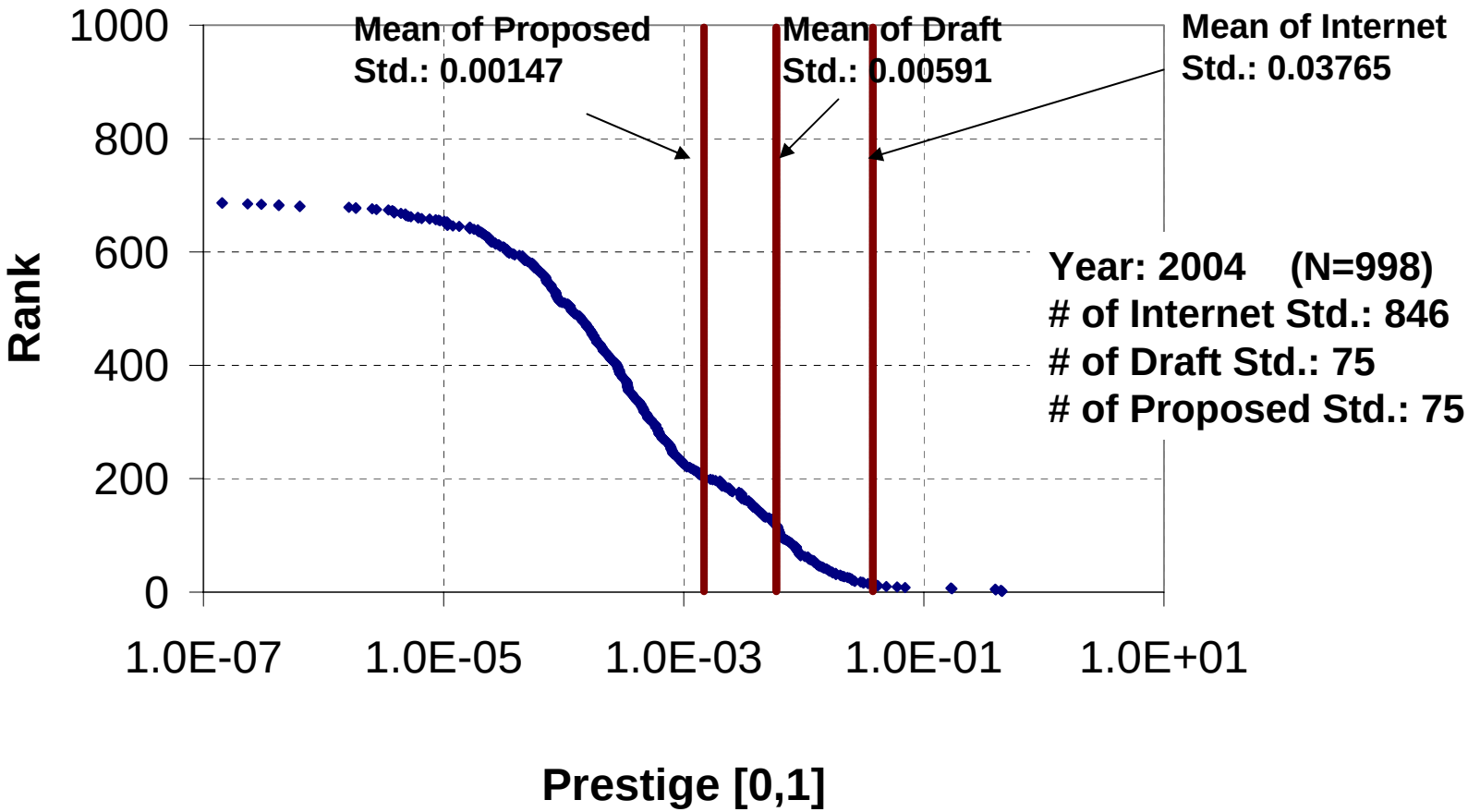
Potential Social Influence of each RFC:

Summation of the centralities of its authors

Promotion Study in IETF Standards (III)

- **RFCs in the higher state** *(i.e. Internet Standards (S) > Draft Standards (D) > Proposed Standards (P))* have:
  - (1) higher prestige values
    - Statistically significant for all pairs of comparison
  - (2) higher summation of authors' centralities
    - Statistically significant for all pairs of comparison

Prestige of Standards vs. Maturity States



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  - (2) higher summation of authors' centralities
    - Statistically significant for all pairs of comparison

Logistic model using standard prestige and co-author centrality shows substantial predictive power when compared to IETF database.

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References

- Mo-Han Hsieh (doctoral thesis work)

- "The Economics of Compatability Standards: An Introduction to Recent Research" by Paul A. David and Shane Greenstein. *Econ. Innov. New Techn.* (1990) [reading for this class]