EE 6886: Topics in Signal Processing -- Multimedia Security System

Lecture 14: Key Managements, Standard, and Emerging Technology

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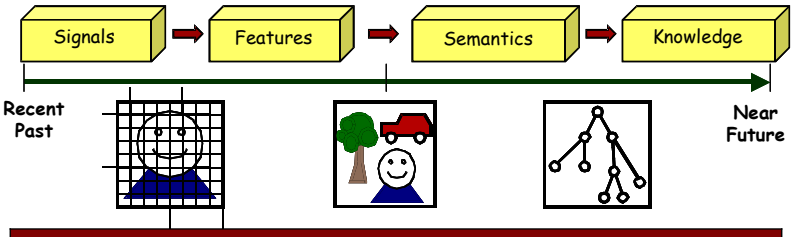
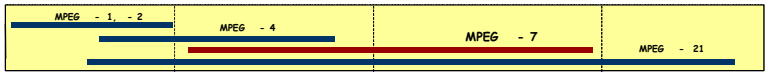
Course Outline

- Multimedia Security :
  - Multimedia Standards – Ubiquitous MM
  - Encryption and Key Management – Confidential MM
  - Watermarking – Uninfringible MM
  - Authentication – Trustworthy MM
- Security Applications of Multimedia:
  - Audio-Visual Person Identification – Access Control, Identifying Suspects
  - Media Sensor Networks – Event Understanding, Information Aggregation
  - Standard and Emerging Technologies

Evolution of Digital Media Applications, Challenges, and Standards

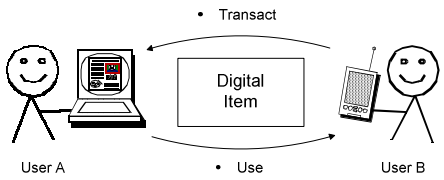


Applications			
❑ **MPEG-1, -2, -4** ❑ Video storage ❑ Broadband ❑ Streaming video and delivery	❑ **MPEG-4, -7** ❑ Content-based retrieval ❑ Multimedia filtering ❑ Content Adaptation	❑ **MPEG-7** ❑ Semantic-based analysis and retrieval ❑ Enterprise content management	❑ **MPEG-21** ❑ E-commerce of electronic content ❑ Flexible business models ❑ Digital items
Problems and Innovations			
❑ Compression ❑ Coding ❑ Communications	❑ Similarity-based searching ❑ Object-based coding	❑ Modeling and classification ❑ Personalization and summarization	❑ Media mining ❑ Decision support ❑ Rights management

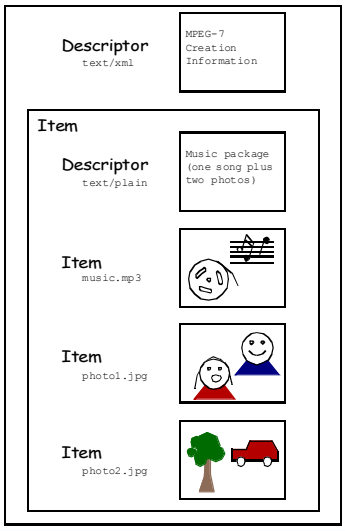


MPEG-21 Multimedia Framework: "Transactions of Digital Items"

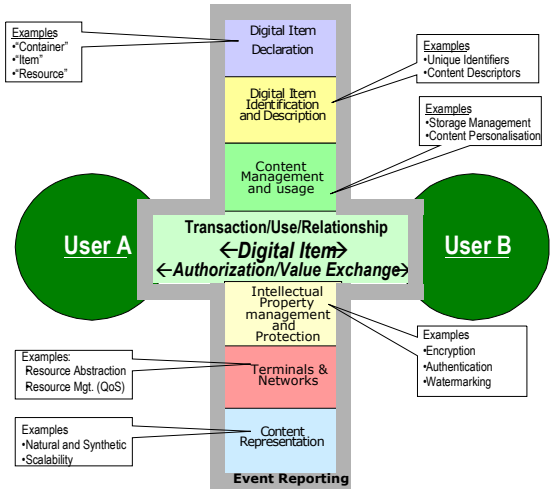
- ❑ Users and participants in the content value chain seamlessly exchange content in form of "digital items" across networks and devices
- ❑ Framework supporting all forms of electronic content/intellectual property (video, music, learning objects, on-line reports, etc.)
- ❑ Digital Item = bundling of:
  - Essence (i.e., media resources)
  - Metadata
  - Rights expressions
  - Identifiers



- ❑ Example: Digital music package

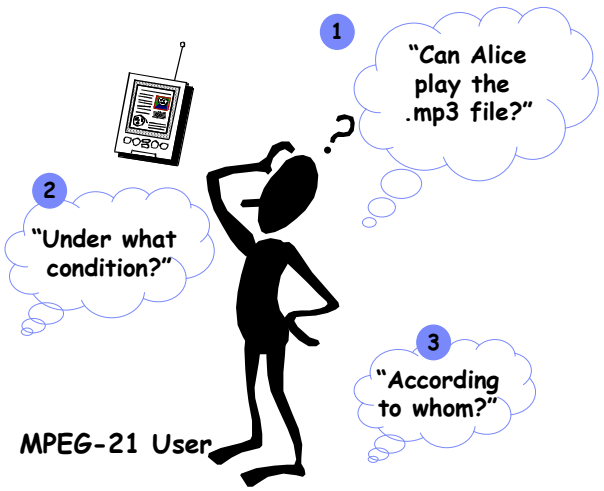


MPEG-21 Standard Framework



- "Interoperable Multimedia Framework"
- "E-Commerce for E-Content"
- "Digital Audio-Visual Framework"
- **Vision**: "To enable transparent and augmented use of multimedia resources across a wide range of networks and devices."
- **Goal**: Integration of technologies for content *identification* and *consumption*
- **Output**: ISO technical report and technical specification (International Standard in 2003)

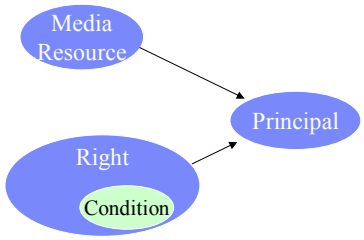
Authorization using MPEG-21 Rights Expression Language



- Rights Expression Language (REL):
  - Specifies a language for declaring rights and permissions associated with use of digital items.
  - The rights expressions use terms as defined in the Rights Data Dictionary.
- Rights Data Dictionary (RDD):
  - Specifies a model and dictionary for clearly and consistently defining terms for use in rights expressions.

Rights Expression Language (XrML) (I)

- XrML 2.0:
  - developed by Xerox
  - adopted by MPEG-21
- Issuer(s) + Grant(s) = License
- Schemas:
  - Core Schema
  - Stand Extension Schema
  - Content Extension Schema



Child Elements of a Grant

- Mandatory Elements in Core Schema:
  - Principal: *all Principal, key holder*
  - Right: *Issue, Revoke, Possess Property, Obtain*
  - Resource: *Digital Resource*
  - Condition: *all Conditions, validity Interval, revocation Freshness, exist Right, pre-requisite Right*
- Optional Elements in Standard Schema:
  - Grant: exercise limit, seek approval, track report, territory, valid time, etc.
  - Fee: cash, payment per use, best price under, etc.
  - Name Extensions: email, dns, common, x509 subject, etc.
  - Revocation Extension: revocable

Rights Expression Language (XrML) (II)

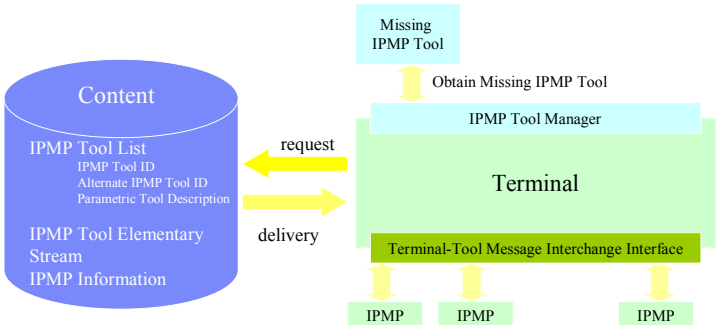
- Optional Elements in Standard Schema:
  - File Management Rights: access, backup, delete, execute, restore, etc.
  - Transport Rights: copy, loan, transfer
  - Derivative Works Rights: edit, embed, extract
  - Render Rights: export, play, print
  - Configuration Rights: install, uninstall
  - Extension to Resources: digital Work, Metadata, security Level,
  - Extension to Condition: destination, source, helper, renderer, watermark

```
<?xml version="1.0" encoding="UTF-8" ?>
<license xmlns=http://www.xrml.org/schema/2001/11/xrml2core …>
  <grant>
    <keyHolder>
      <info>
        <dsig:KeyValue>
          <dsig:RSAKeyValue>
            <dsig:Modulus>Fa7wo6NYfmvGqy4ACSWcNmuQfbejSZx</dsig:Modulus>
            <dsig:Exponent>AQABAA==</dsig:Exponent>
          </dsig:RSAKeyValue>
        </dsig:KeyValue>
      </info>
    </keyHolder>
    <possessProperty />
      <sx:commonName>Alice Richardson</sx:commonName>
  </grant>
</license>
```

A sample XrML Grant

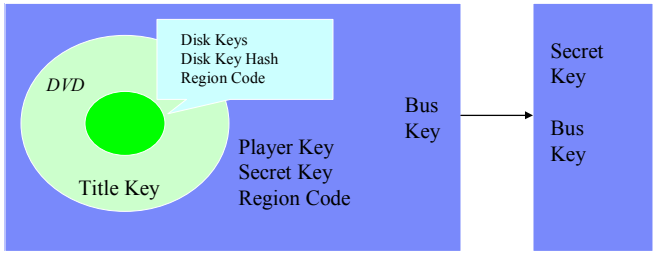
MPEG IPMP Extension

- Applied to any MPEG multimedia representation
- Objectives:
  - Allow the same protected content to be consumed on different vendors' Terminals.
  - Allow the same content to be protected by different vendors' IPMP Tools.



Architecture Diagram

DVD Content Scramble System Overview



DVD Player Host

Content De-scrambling Process:

- Mutual Authentication
- Decoding disk
- Send disk and title keys
- Send sectors
- Host decodes the title key using the disk key
- The host decodes the sector using the title key and the sector key

DVD Content Scramble System

Linear Feedback Shift Register (LFSR):
- generating pseudo-random bit stream
- use this bit stream to XOR it with the original stream
- the decoder uses XOR again to get the original stream

Disk and Player Keys
- each player has a small number of keys
- each disk is encoded by a disk key.
- each disk contains a hidden sector
- the hidden sector contains the disk key encrypted with all 409 possible player keys.
- it holds the disk key encrypted with the disk key.
- the player decrypts the appropriated entry and then verifies that it has correctly decoding the disk key, by decoding the decrypted disk key.

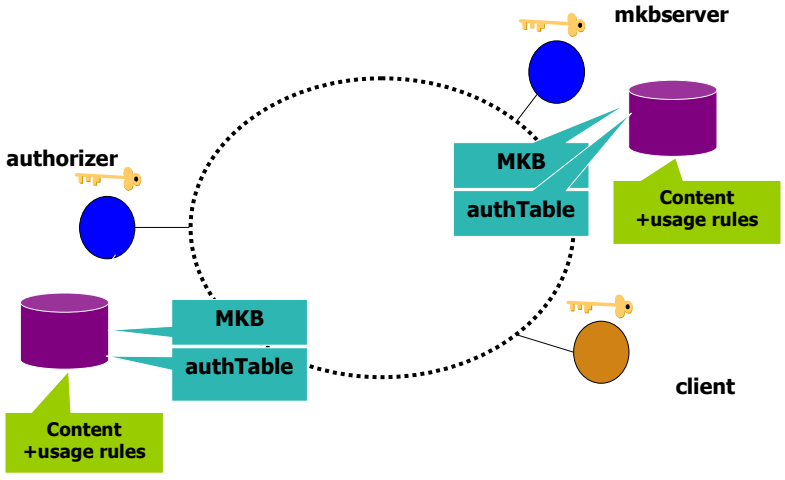
Encryption and Key Managements

- 5C DTCP (Digital Transmission Content Protection):
  - Authentication and data encryption with a digital bus (primarily the IEEE 1394 Firewire bus).
  - Supported by Hitachi, Intel, Matsushita, Sony and Toshiba.
- Cisco OCCAM (Open Conditional Content Access Management):
  - Public key infrastructure with a central authority
  - One-way protocols lead to more robust implementations
- IBM xCP Cluster Protocol
  - Broadcast encryption
  - Derived from Content Protection for Recordable Media (supported by IBM, Matsushita, Intel and Toshiba).

Broadcast Encryption

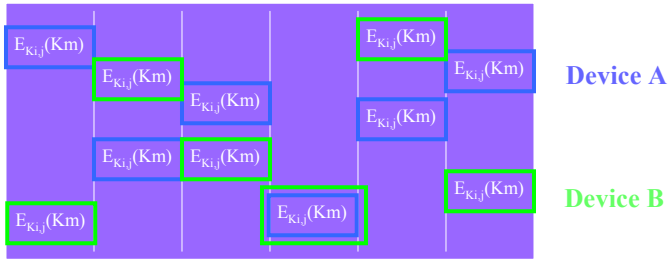
- Algorithmic Lineage
  - Broadcast encryption - Fiat and Naor, Crypto '93
  - Tracing traitors - Chor et al., Crypto '94
- Alternative to Public Key Encryption
  - 2 or 3 orders of magnitude less overhead
  - One-way protocols lead to more robust implementations
- Supports key revocation
  - Unlike global secret schemes in which a single hacking event breaks the whole system

Cluster Model



Media Key Blocks

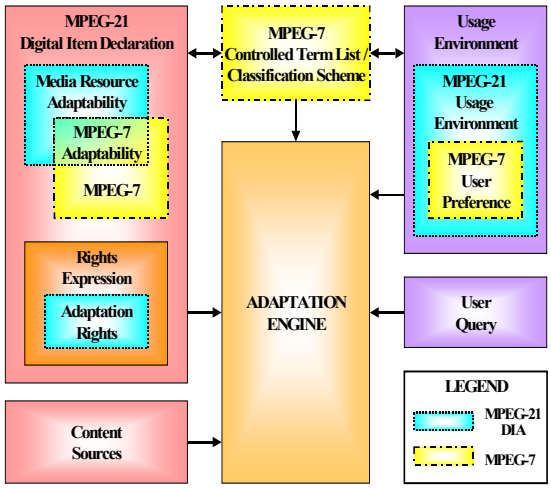
- Scheme is large matrix of random keys
- Each device assigned one key from each column



MKB is data structure w/multiple ciphers of same media key under different device keys

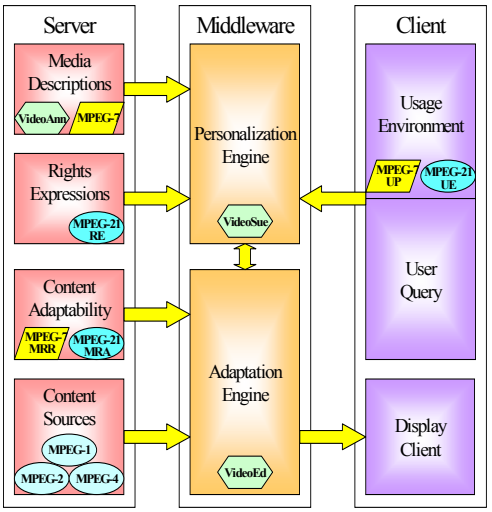
Digital Item Adaptation
using MPEG-7 and MPEG-21

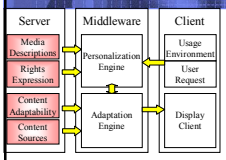
- Media Description
  - MPEG-7 Description Schemes
- Usage Environment
  - MPEG-7 User Preferences
  - MPEG-21 Usage Environment
- Content Adaptability
  - MPEG-7 Media Resource Requirement
  - MPEG-21 Media Resource Adaptability



A Personalization and Summarization System Architecture

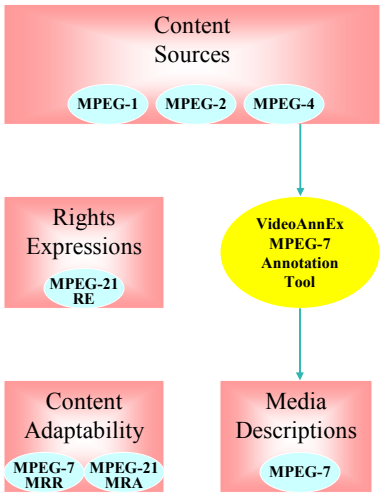
- Database Server
  - Content Sources
  - MPEG-7 Media Descriptions
  - MPEG-21 Rights Expression
  - Content Adaptability
- Media Middleware
  - Select Personalized Contents in Personalization Engine
  - Retrieve and Adapt Contents in Adaptation Engine
- User Client
  - Request for Personalized Content
  - Communicate Usage Environment

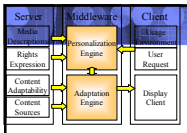




Database Server

- Media Descriptions
  - MPEG-7 DS
- Rights Expression
  - MPEG-21 RE
- Content Adaptability
  - MPEG-7 Media Resource Requirement
  - MPEG-21 Media Resource Adaptability





Media Middleware

Personalization Engine

Content Selection
Video selections
Scene selections

Format Selection
Format, frame rate
display size, color

MPEG-7 Metadata Catalog

Usage Environment

User Query

Content Adaptation Engine

Format Transcoder
Video, Image
Audio, Text

Scale Transcoder
Frame rate,
display size, color

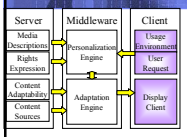
Presentation Composer
Spatial composition
Temporal ordering

Rich media

Content Repository

T E X T

Pervasive access



User Client

- Usage Environment
  - Persistent Data
  - User Profile
    English speaker, NYC resident
  - Device Profile
    color display, audio capability
  - Transmission Profile
    56K modem, ethernet
- User Query
  - User Specific Preferences
    keyword search, CBR

Middleware

Personalization Engine

DID Parser

Request Parser

Processing Engine
Summarization
Semantic Query
Feature-Based Query
Content Selection
Format Decision

Adaptation Engine

HTTP REQUEST

•MPEG-21 DIA (user environment)
•MPEG-7 (user preference)
•W3C CC/PP

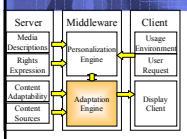
Content

User Client

Usage Environment
User Profile
Device Profile
Transmission Profile

User Query
Topic Preference
Query Keywords
Time Constraints

Display Client
PCs (Browser, Application)
PDAs (Palm, WinCE)
Phones/Watches (WAP, Jini)



Media Middleware
Video Summarization on Usage Environment

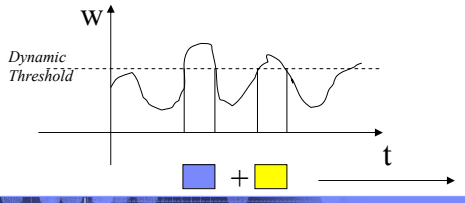
P = user preference vector, where p_i denotes the preference weighting for concept i.
A = attribute matrix, where score $a_{i,j}$ is defined as the relevance of concept i in shot j.
W = weighted importance vector, where w_i is the weighted concept for shot i.

video segment weighting

attribute relevance matrix

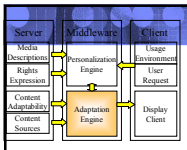
user preference vector

$$\bar{W} = \begin{bmatrix} w_1 \\ w_2 \\ \dots \\ w_M \end{bmatrix} = \begin{bmatrix} a_{1,1} & a_{1,2} & \dots & a_{1,N} \\ a_{2,1} & \dots & \dots & \dots \\ \dots & \dots & a_{i,j} & \dots \\ a_{M,1} & \dots & \dots & a_{M,N} \end{bmatrix} * \begin{bmatrix} p_1 \\ p_2 \\ \dots \\ p_N \end{bmatrix}$$

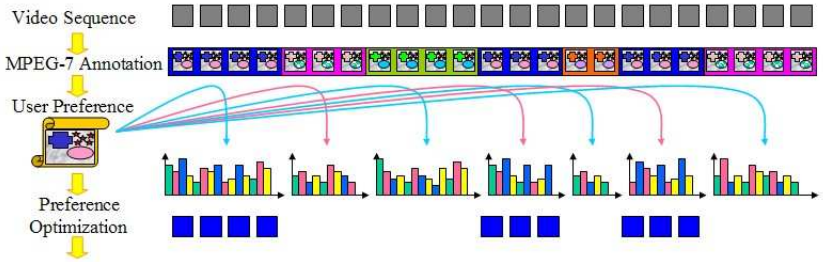


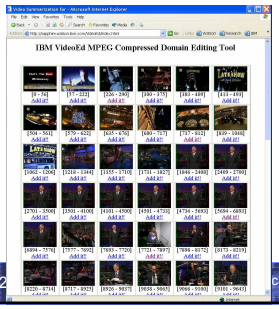
A is generated manually, semi-automatically, or automatically

Summarized video

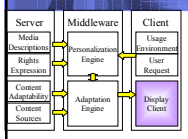


Media Middleware
Compressed-Domain MPEG Editing Tool



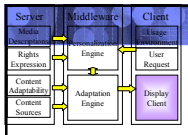


- Run-time user selection of video shots
- Fast creation of personalized summaries
- On-line preview of editing results
- Compatible with MPEG-1 and MPEG-2
- Demo http://sapphire.watson.ibm.com/VideoEd



User Client
PDA Devices

- Browsing
  - Channels
  - Links
- Preferences
  - Video Source
  - Preferences
  - Time Constraint
- Queries
  - Topics
  - Keyword Search
  - Time Constraints



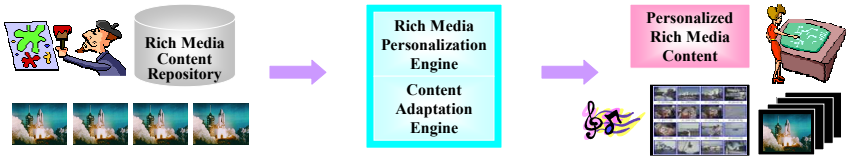
User Client
IBM Websphere Portal Server

- Usage Environment
  - User Preference Topics
    [news, entertainment, education]
  - Device [terminal, PDA]
  - Network Constraint
- User Query
  - Topic Preferences
  - Keyword Search
  - Time Constraint

Interoperable Multimedia Content Management:
Relevant Standards – MPEG-7 and MPEG-21

- Metadata is critical for describing essential aspects of content:
  - Main topics, author, language, publication, etc.
  - Events, scenes, objects, times, places, etc.
  - Rights, packaging, access control, content adaptation, etc.
- Conformity with open metadata standards will be a vital:
  - Allows faster design and implementation
  - Interoperability with broad field of competitive standards-based tools and systems
  - Leveraging of rich set of standards-based technologies for critical functions such as content extraction, advanced search, and personalization
- Relevant critical standards for interoperable multimedia CM:
  - MPEG 7 Multimedia Content Description Interface
    - ISO/IEC standard for multimedia metadata (XML-Schema based)
  - MPEG 21 Multimedia Framework
    - ISO/IEC standard for transactions of digital items, rights management, and content adaptation
- Summary of benefits:
  - MPEG-7 allows interoperability of systems and tools for multimedia content analysis, annotation, indexing, searching, and filtering
  - MPEG-21 allows interoperable transactions of digital multimedia content

Summary of Video Personalization and Summarization



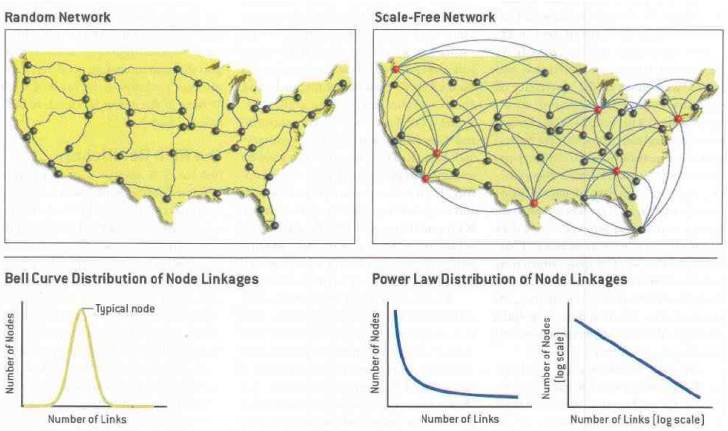
- Video Personalization and Summarization System allows universal access and personalized content of rich media to any user environment at anytime and anywhere
- Innovations
  - Standards-based (MPEG-7 & MPEG-21) interoperable solution
  - Off-line semi-automatic MPEG-7 XML content annotation
  - Digital item adaptation and transactions using MPEG-21
  - Optimized content adaptation to user query and user environment
  - Real-time compressed domain video composer for MPEG contents
- Applications
  - Enterprise rich media (i.e., e-Learning, video conferencing, news, communications)
  - Wireless (i.e., personalized video clips, image slide shows)
- Conclusion
  - Methods for automatic rich media annotation, indexing, retrieval, and optimized personalization and presentation

Emerging Technologies

- Complex Network Analysis

An example of complex network: Power-Law Network

- A. Barbasi and E. Bonabeau, "Scale-free Networks", Scientific American 288: p.50-59, 2003.



$$p_k = e^{-m} \cdot \frac{m^k}{k!}$$

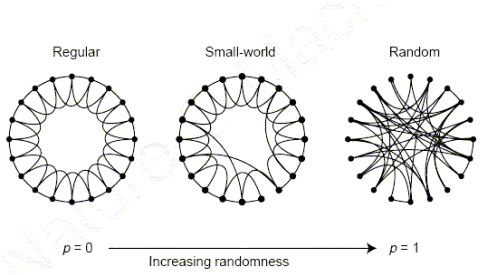
$$p_k = C \cdot k^{-\tau} e^{-k/\kappa}$$

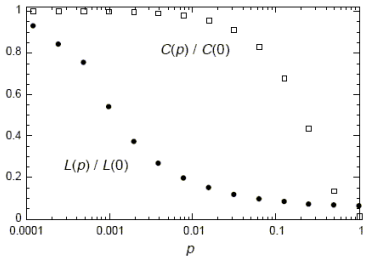
Newman, Strogatz and Watts, 200

Another example of complex network: Small-World Network

- Six Degree Separation:
  - adding long range link, a regular graph can be transformed into a small-world network, in which the average number of degrees between two nodes become small.

from Watts and Strogatz, 1998





C: Clustering Coefficient, L: path length,
(C(0), L(0)): (C, L) as in a regular graph;
(C(p), L(p)): (C,L) in a Small-world graph with randomness p.

What is a complex network?

- Most real-world networks have complex topological features:
  - Heavy-tail in the degree distribution
  - High clustering coefficient
  - Assortativity or Disassortativity among vertices
  - Community structure at many scales
  - Self-similar hierarchical structure

- Simple networks:
  - Typically represented by graphs such as a lattice or a random graph.
  - Topology structure roughly the same in any part of network.
  - Does not posses the above features

- Examples:
  - Social Networks – studied in sociology, public health, commerce, communication.
  - Computer Networks – WWW, security,…
  - Biological Networks – neurons, genes, protein, animals,…
  - Others: sensor network, river network, power lines, …

Relationships are multi-dimensional and uncovered through network questions

Actions

Communication
How often do you communicate with this person?

Innovation
How often do you turn to this person for new ideas

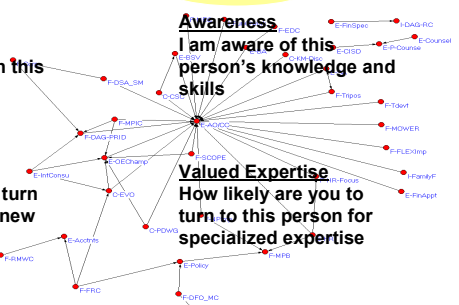
Advice
How often do you seek advice from this person before making an important decision?

Awareness

Awareness
I am aware of this person's knowledge and skills

Valued Expertise
How likely are you to turn to this person for specialized expertise

Learning
How likely are you to rely on this person for advice on new methods and processes



Emotional

Trust
I believe there is a high personal cost in seeking advice or support from this person

Access
I believe this person will respond to my request in a reasonable and timely manner

Energy
I generally feel energized when I interact with this person

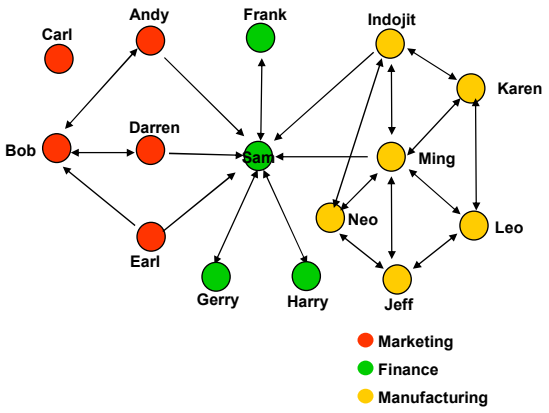
This slide is excerpted from SNA Theory, Concepts and Practice by Dr. T. Mobbs, BCS and Dr. K. Ehrlick, Research

Group and Roles

Central people
- Sam. Could be bottleneck or holding group together

Peripheral people
- Earl. Goes to others but no-one goes to him for information. At risk for leaving. Potentially unrealized expertise

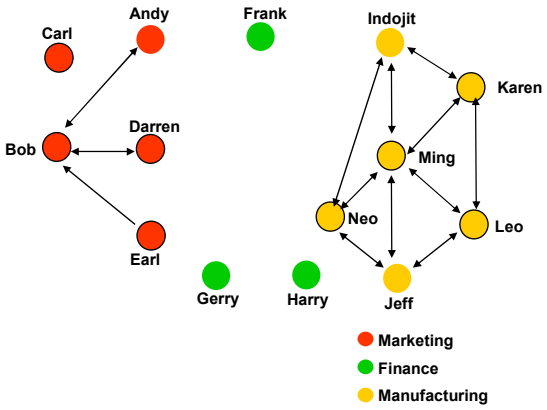
Sub-groups
- Group split by function. Very little information shared across groups



This slide is excerpted from SNA Theory, Concepts and Practice by Dr. T. Mobbs, BCS and Dr. K. Ehrlick, Research

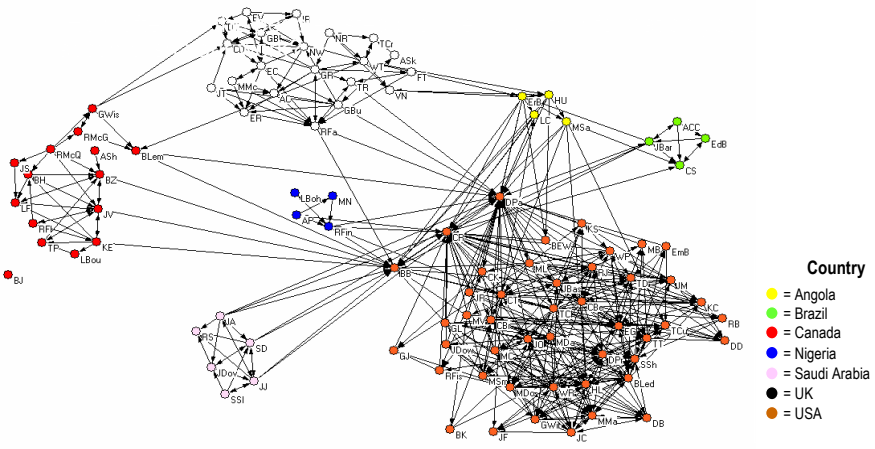
Some Roles are especially critical

What happens if Sam leaves the group through layoffs, job reassignment, attrition, merger, retirement?



This slide is excerpted from SNA Theory, Concepts and Practice by Dr. T. Mobbs, BCS and Dr. K. Ehrlick, Research

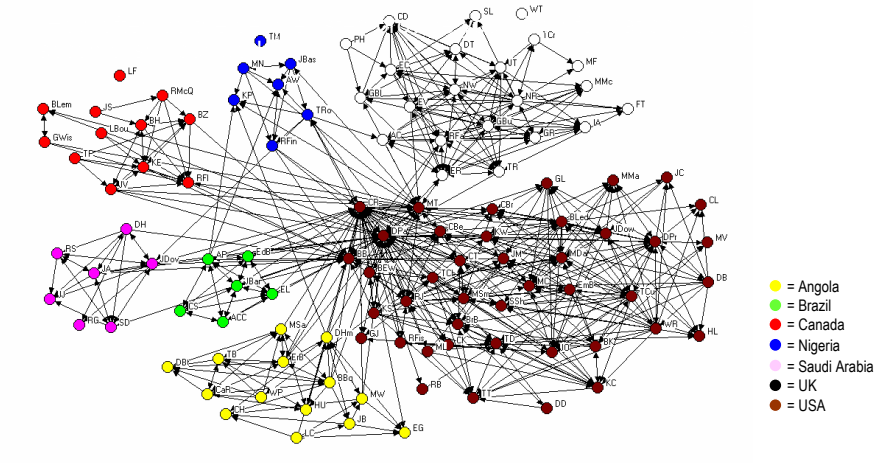
Attributes can create barriers to collaboration



The connections show that very little communication occurs between countries.

This slide is excerpted from SNA Theory, Concepts and Practice by Dr. T. Mobbs, BCS and Dr. K. Ehrlick, Research

Revealing problems can provoke solutions

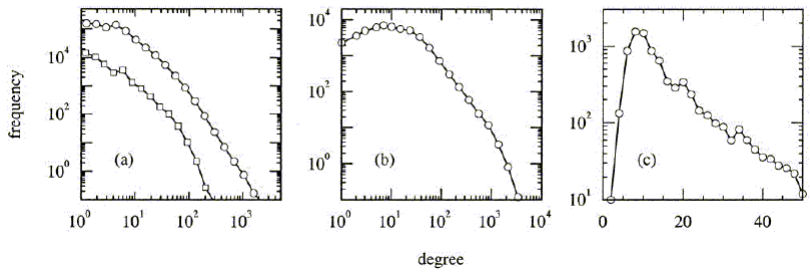


A follow-up SNA 14 months later showed great improvement

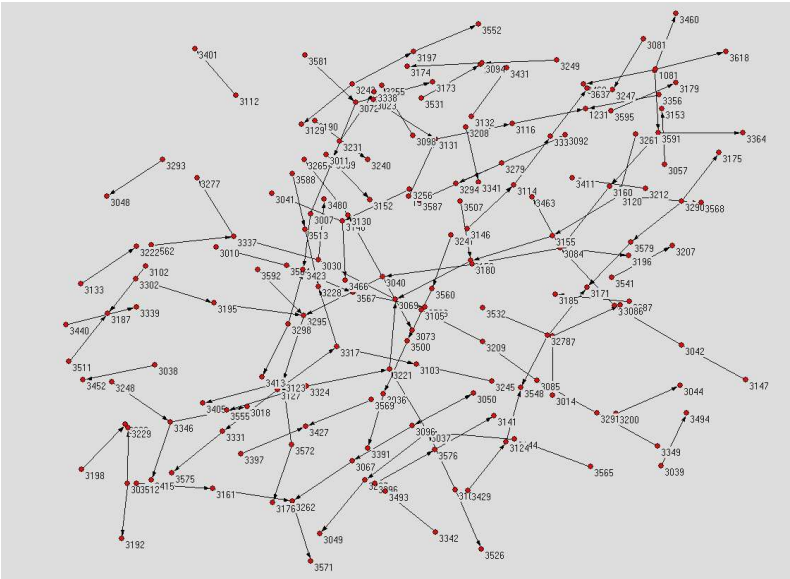
This slide is excerpted from SNA Theory, Concepts and Practice by Dr. T. Mobbs, BCS and Dr. K. Ehrlick, Research

Some examples of Degree Distribution

- (a) scientist collaboration: biologists (circle) physicists (square), (b) collaboration of move actors, (d) network of directors of Fortune 1000 companies

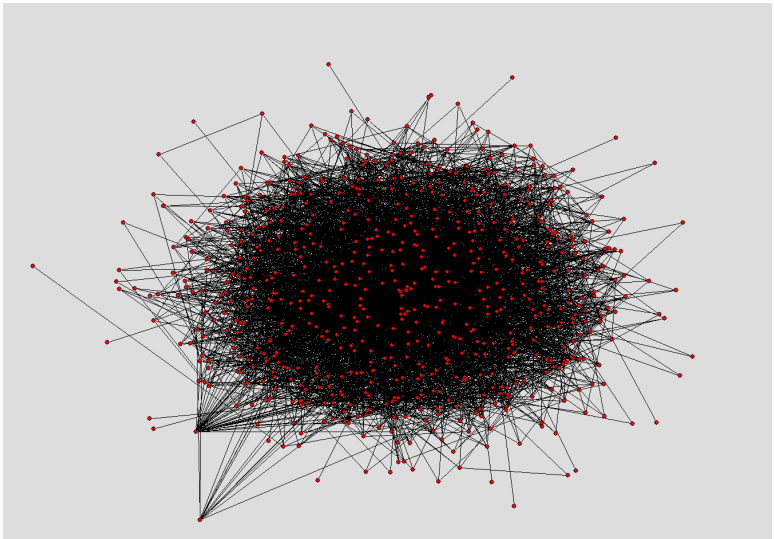


Social Network of Switchboard-2 Subset



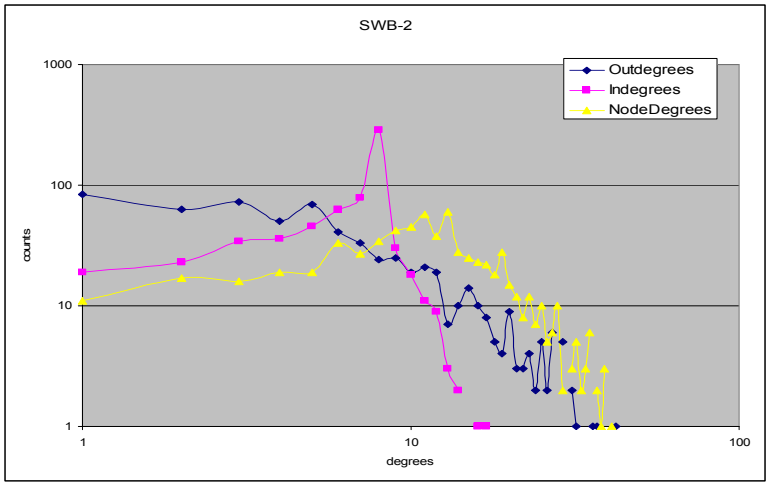
Social Network of Switchboard-2 Dataset

- 679 nodes ➔ edges = 4472



Switchboard-2 Network Degree Distribution

- 679 nodes (actors)
- Out degrees ➔ Normal. In degrees ➔ Abnormal.



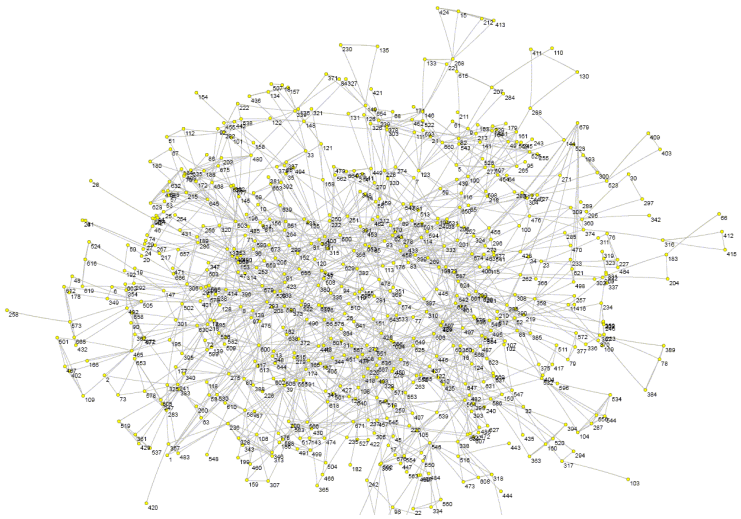
The Most Difficult Challenge: State-of-the-Arts?

➔ **Our Objectives: Find important people, community structures, or information flow in a network, which is *dynamic*, *probabilistic* and *complex*, in order allocate resources in a large-scale mining system.**

- Social Networks in sociological and statistic fields: focus on (1) overall network characteristics, (2) dynamic random graphs, (3) binary edges, etc. ➔ Not consider probabilistic nodes/edges or individual nodes/edges.
- Epidemic Networks & Computer Virus Network: focus on (1) overall network characteristics – when will an outbreak occurs, (2) regular / random graphs. ➔ Not focus on individual nodes/edges.
- (Computer) Communication Networks: focus on (1) packet transmission – information is not duplicated, or (2) broadcasting – not considering individual nodes/edges or complex network topology.
- WWW: focus on (1) topology description, (2) binary edges and ranked nodes (e.g., Google PageRank) ➔ Not consider probabilistic edges

What is a Dynamic Probabilistic Complex Network?

- Example: http://alishan.watson.ibm.com/NetDIG/



Modeling a Dynamic Probabilistic Complex Network

- [*Assumption*] A DPCN can be represented by a Dynamic Transition Matrix ***P(t)***, a Dynamic Vertex Status Random Vector ***Q(t)***, and two dependency functions f_M and g_M.

$$\mathbf{P}(t) \triangleq \begin{bmatrix} \mathbf{p}_{1,1}(t) & \mathbf{p}_{2,1}(t) & \cdots & \cdots & \mathbf{p}_{N,1}(t) \\ \mathbf{p}_{1,2}(t) & \mathbf{p}_{2,2}(t) & & & \mathbf{p}_{N,2}(t) \\ \vdots & \vdots & \ddots & & \vdots \\ \vdots & \vdots & & \ddots & \vdots \\ \mathbf{p}_{1,N}(t) & \mathbf{p}_{2,N}(t) & \cdots & \cdots & \mathbf{p}_{N,N}(t) \end{bmatrix}, \quad \mathbf{Q}(t) \triangleq \begin{bmatrix} \mathbf{q}_1(t) \\ \mathbf{q}_2(t) \\ \vdots \\ \vdots \\ \mathbf{q}_N(t) \end{bmatrix},$$

$$\mathbf{P}(t+\delta t) \triangleq f_M(\mathbf{Q}(t), \mathbf{P}(t)),$$

and

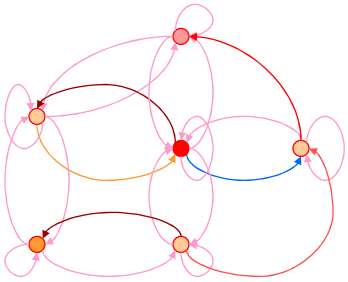
$$\mathbf{Q}(t+\delta t) \triangleq g_M(\mathbf{P}(t+\delta t), \mathbf{Q}(t), \mathbf{P}(t)),$$

where

$$\mathbf{p}_{i,j}(t) \triangleq \begin{bmatrix} \Pr(y_{i,j}(t) = SE_1) \\ \Pr(y_{i,j}(t) = SE_2) \\ \vdots \\ \Pr(y_{i,j}(t) = SE_{\Omega_E}) \end{bmatrix}, \quad \mathbf{q}_i(t) \triangleq \begin{bmatrix} \Pr(x_i(t) = SV_1) \\ \Pr(x_i(t) = SV_2) \\ \vdots \\ \Pr(x_i(t) = SV_{\Omega_V}) \end{bmatrix},$$

$$\sum_{\omega \in \Omega_E} \Pr(y_{i,j}(t) = SE_\omega) = 1, \qquad \sum_{\omega \in \Omega_V} \Pr(x_i(t) = SV_\omega) = 1,$$

and $x_i(t)$: the status value of vertex i at time t.
$y_{i,j}(t)$: the status value of edge $i \rightarrow j$ at time t.



Modeling a Dynamic Probabilistic Complex Network – cont'd

- Also the Network Topology should follow the characteristics of complex network:

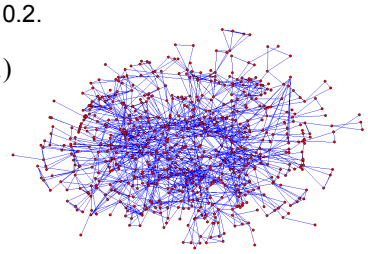
Network topology follows power-law:

$$\Pr(\sum_i \mathrm{u}(p_{i,j}) = l) \sim S \cdot l^{-d} \qquad \text{where } \mathrm{u}(p_{i,j}) = \begin{cases} 1, & if\ \exists t, \Pr(y_{i,j}(t) \neq null) > 0 \\ 0, & else \end{cases}$$

d is typically in the range of $2 \sim 2.5$.

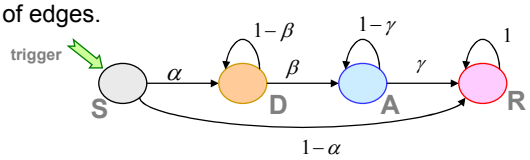
and the clustering coefficient C is typically > 0.2.

$$C = \Pr(\mathrm{u}(p_{j,k}) = 1 \mid \mathrm{u}(p_{i,j}) = 1, \mathrm{u}(p_{i,k}) = 1)$$



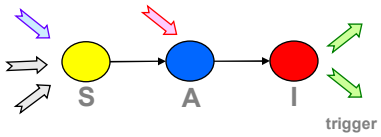
Edges are Markov State Machines, Nodes are not

- State transitions of edges: S-D-A-R model. (Susceptible, Dormant, Active, and Removed) This indicates the time-aspect changes of the state of edges.

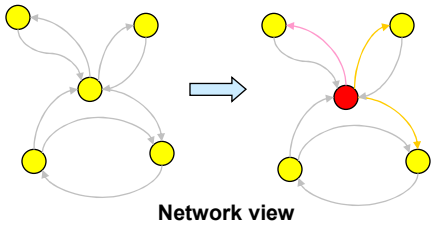


Edge view

- States of nodes: S-A-I model. (Susceptible, Active, and Informed) Trigger occurs when the start node of the edge changes from state S to state I :



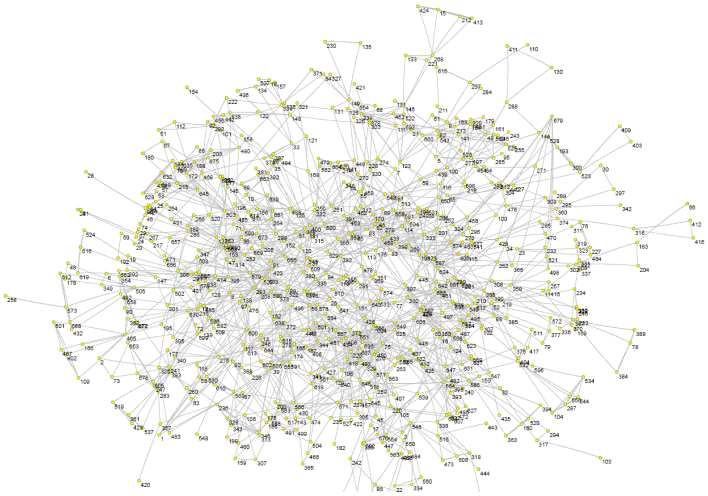
Node view



Network view

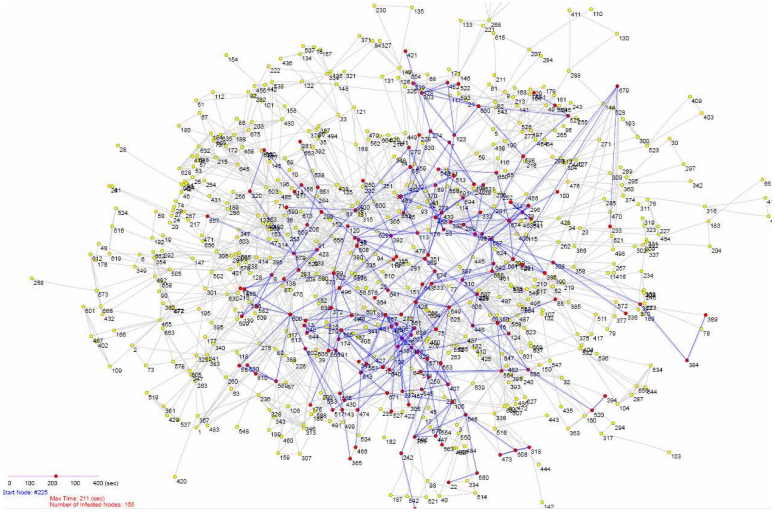
Advanced Modeling -- Dynamic Probabilistic Social Network [Lin 2006]

- Social networks are usually evolving -- that the relationships and actions of actors are dynamic and probabilistic



Dynamic Probabilistic Social Network Analysis

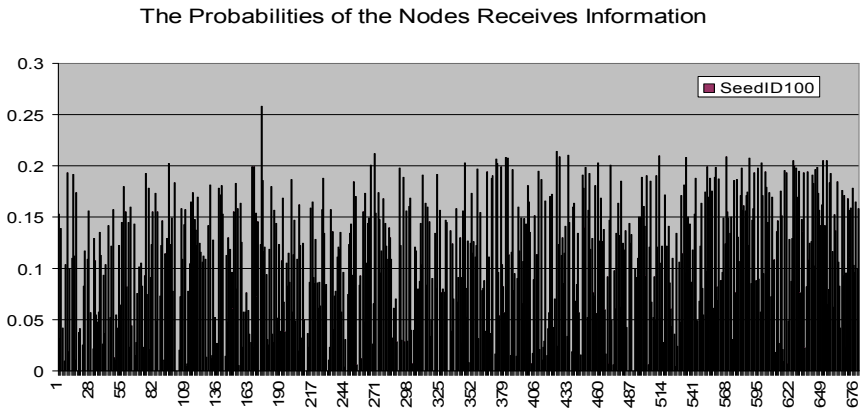
- Predict Information Flow based on DPSN analysis – e.g. Phone calls of 679 Midwest universities students.



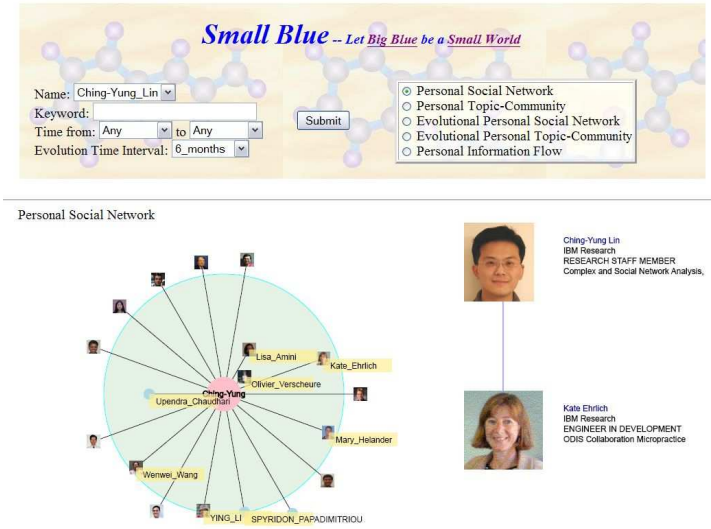
Red: Informed People
Blue: Activated Communications
Yellow: Not-Informed people

Predicting behavioral information flow based on DPSN

- If information starts spreading from Actor 100, what are the probabilities that the other people got informed?

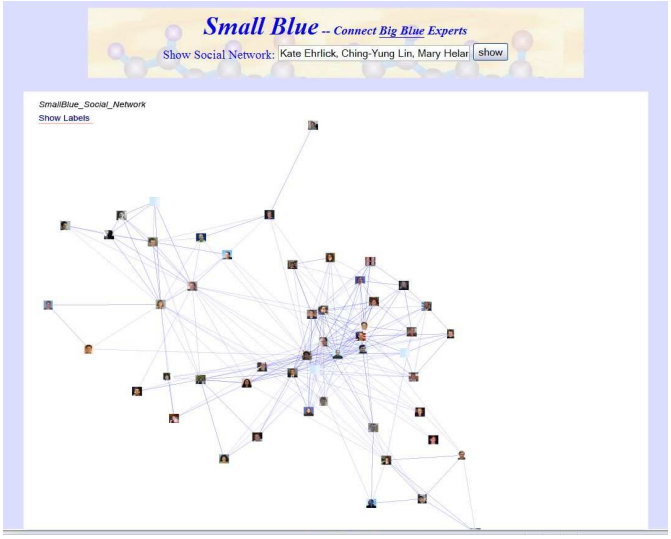


SmallBlue Ego-- Who does a person know and collaborate?



SmallBlue Find-- find an expert with *useful* knowledge in corporate

SmallBlue Connect – Link people's knowledge, expertise and social connections



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- ISO/IEC JTC 1/SC 29/WG 11 N4269, “Information Technology – Multimedia Framework (MPEG-21) – Part 4: Intellectual Property Management and Protection,” July 2001.
- G. Kesden, “Introduction on Content Scrambling System,” Lecture on Operating Systems: Design and Implementation, CMU, Dec. 2000.
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- Belle L. Tseng, Ching-Yung Lin and John R. Smith, "**Video Personalization and Summarization System based on MPEG-7 and MPEG-21**," *IEEE Multimedia Magazine*, Jan.-Mar., 2004.
- C.-Y. Lin, X. Song, M.-T. Sun and B. L. Tseng, "***Automatic Modeling of Social Networks through Content Analysis of Communications*** ," Sunbelt 26th Social Network Conference, Vancouver, Canada, April 2006.

Review of Course

- Multimedia Security :
  - Multimedia Standards – Ubiquitous MM
  - Encryption and Key Management – Confidential MM
  - Watermarking – Uninfringible MM
  - Authentication – Trustworthy MM
- Security Applications of Multimedia:
  - Audio-Visual Person Identification – Access Control, Identifying Suspects
  - Media Sensor Networks – Event Understanding, Information Aggregation
  - Standard and Emerging Technologies

Final Project

- Due on May 12 (Friday).
- If you are a graduating student, please submit your final project to TA and me by noon May 12.
- Presentation on May 10. Format is similar to the project proposal.
- Demo or online webpages will be welcome.