Introduction to Bayesian Networks

Assoc Prof Dr. Ting Choo Yee

Objectives

- Towards the end of this knowledge sharing, you should be able to
  - Define the properties of Bayesian Networks.
  - Apply Bayesian Networks to solve real world problems.

PART 1

(Introduction to Bayesian Networks)

Examples of Applications of Bayesian Networks

- Anti-spam filter– SpamBayes (http://spambayes.sourceforge.net/index.html)
- Medical diagnostic systems
- Intel processor fault diagnosis (Intel);
- Generator monitoring expert system (General Electric);
- Software troubleshooting (Microsoft office assistant, Win98 print troubleshooting)
- Space shuttle engines monitoring(Vista project)
- Biological sequences analysis and classification
- …

Characteristics of Problems…

- Suitable for problems dealing with Classification – to predict a particular grouping or segmentation.
- Works well under the following scenario:

1. Expert Input is sufficient
2. Expert Input + data
3. Only dataset available (no expert)

Characteristics of domains…

1

- Domains that can be represented by variables.
- E.g.:
  - The domain = *Country risk*
  - The variables = "political instable", "corruption", "stock market performance"
  - The states (values) can be both discrete or continuous

Characteristics of domains…

2

- Variables can be represented through a set of cause-and-effect relations.
  - If you eat a lot of "*nasi lemak*", there is a chance for you get fat!
  - That is "*nasi lemak*" is a cause to fatness.

Characteristics of domains…

3

- evidence can be captured.
  - In an election, Party A has a high chance to win because *statistics results*, *a lot of "likes" to Party A*, and etc .
  - The patient has Dengue Fever because rashes, high-fever, bleeding, and etc.

Characteristics of domains…

4

- May involve properties that evolve over time
  - After 3 days of medical attention, the patient is predicted slowly recovering from dengue fever because *the platelet level increases, the body temperature drops to 37.5°C, body pain reduces*…etc

Characteristics of domains…

5

- Need to have decision making given uncertain events.
  - What are the most probable choices given that a patient is in this condition?

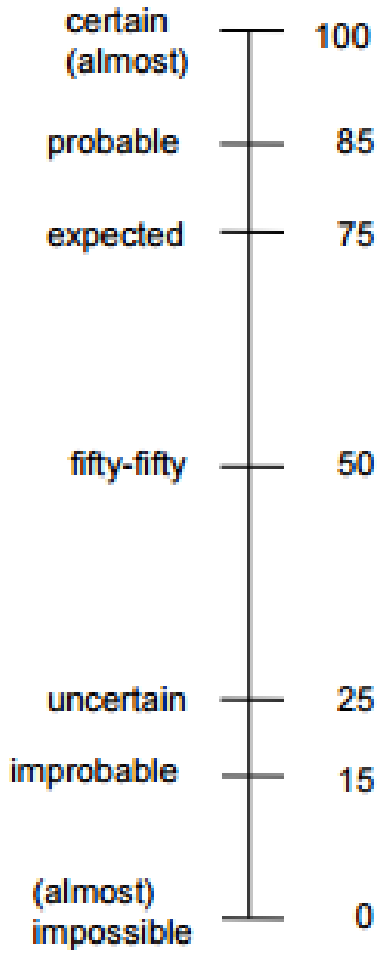
Tools to Create a Bayesian Networks

- Tools to create a BN, not limited to:
  - Commercialized Products:
    - Hugin
    - Netica
    - Bayesia
  - Research Products:
    - BNT for MathLab
    - GeNIe and SMILE (for .NET and Java)
    - JavaBayes
    - MSBNx

Constructing a Bayesian Network

- Arcs in a Bayesian Network are interpreted as indicating cause-effect relationships
- Build a causal network:
  - Choose a set of variables that describes the domain. Variables (chance nodes) are represented by *oval* / *round* shapes.
  - Draw an arc to a variable from each of its *direct* causes (Domain knowledge required)
- E.g. A causes B

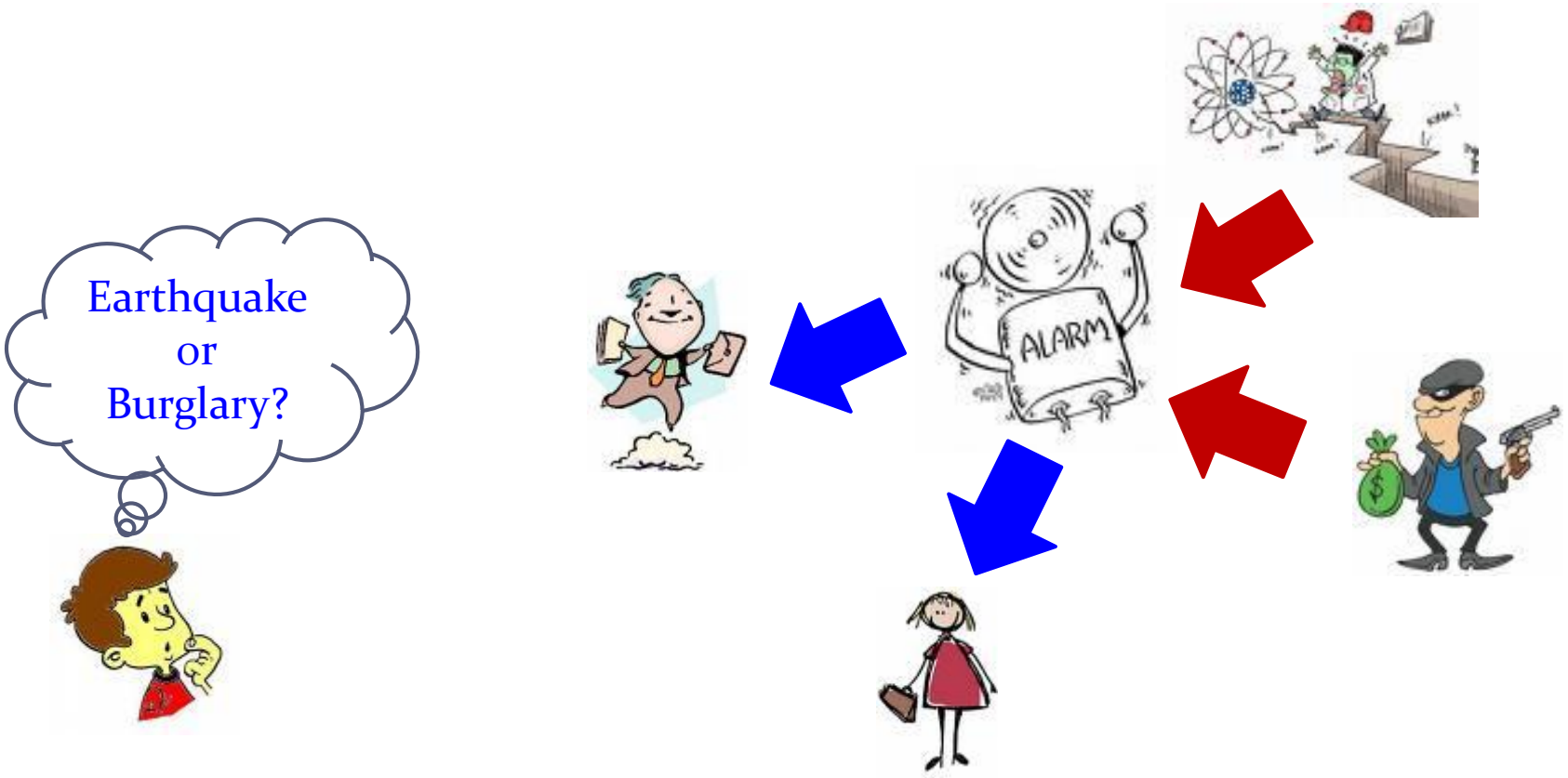
Probability Scale



Verbal description of probability	Probability interval
high	0.7 - 1.0
moderate	0.3 - 0.7
low	0.05 - 0.3
very low	0.001 - 0.05
extremely low	10^{-6} - 0.001
negligible	0 - 10^{-6}

An Example – Alarm

- The scenario:
  - Assuming that burglary and earthquake can cause alarm. In case of alarm, two neighbors John and Mary may call



An Example – Alarm

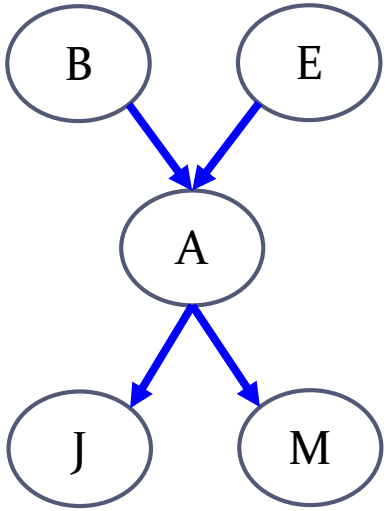
- Problem:
  - Estimate the probability of a burglary based who has or has not called
- Variables:
  - Burglary (B), Earthquake (E), Alarm (A), JohnCalls (J), MaryCalls (M)
  - Each variable has only two states – **y** or **n**.

An Example – Alarm

"Map" the scenario into BN

P(B)=0.2

P(E)=0.4



P(A|B,E)=0.9
P(A|B,not E)=0.8
P(A|not B,E)=0.7
P(A|not B, not E)=0.1

P(J|A)=0.8
P(J|not A)=0.6

P(M|A)=0.8
P(M|not A)=0.1

Why using a BN, not Joint Probability

- If using a full joint probability distribution, we need 32 numbers.

Defining this table is tedious!

$P(B, E, A, J, M)$

B	E	A	J	M	Prob	B	E	A	J	M	Prob
y	y	y	y	y	.00001	n	y	y	y	y	.0002
y	y	y	y	n	.000025	n	y	y	y	n	.0004
y	y	y	n	y	.000025	n	y	y	n	y	.0004
y	y	y	n	n	.00000	n	y	y	n	n	.0002
y	y	n	y	y	.00001	n	y	n	y	y	.0002
y	y	n	y	n	.000015	n	y	n	y	n	.0002
y	y	n	n	y	.000015	n	y	n	n	y	.0002
y	y	n	n	n	.0000	n	y	n	n	n	.0002
y	n	y	y	y	.00001	n	n	y	y	y	.0001
y	n	y	y	n	.000025	n	n	y	y	n	.0002
y	n	y	n	y	.000025	n	n	y	n	y	.0002
y	n	y	n	n	.0000	n	n	y	n	n	.0001
y	n	n	y	y	.00001	n	n	n	y	y	.0001
y	n	n	y	n	.00001	n	n	n	y	n	.0001
y	n	n	n	y	.00001	n	n	n	n	y	.0001
y	n	n	n	n	.00000	n	n	n	n	n	.996

Reasoning with BNs

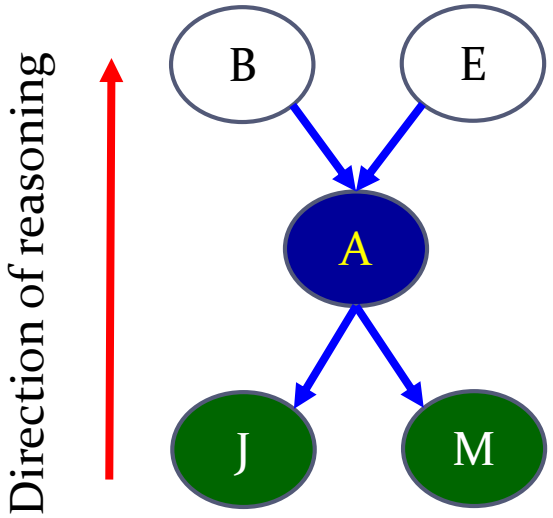
- When we observe of some variables, we would like to condition upon the new information.
- The process of conditioning (also called *probability propagation* or *inference* or *belief updating*) is performed via a "flow of information" through the network.
- The information flow is *NOT* limited to the directions of the arcs.

Reasoning with BNs

- A BN can perform two types of reasoning:
  - *Diagnostic Reasoning*
  - *Predictive Reasoning*

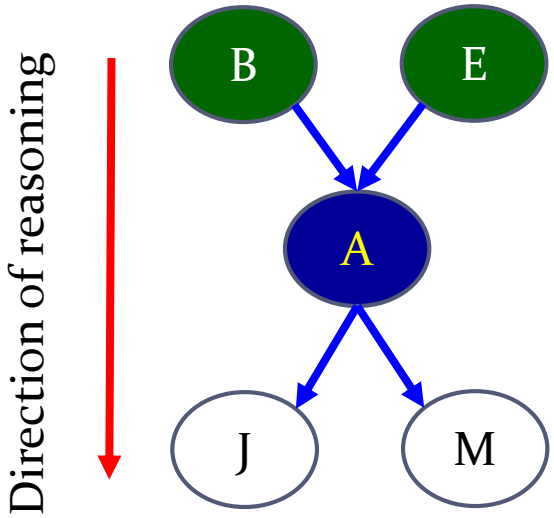
Reasoning with BNs

- Diagnostic Reasoning
  - Reasoning from ***symptoms*** (*effects*) to ***cause(s)***.
  - The symptoms are ***evidence*** to infer the cause. That is, to obtain the ***posterior probability*** of the cause.
  - The leave nodes are *observable* (*evidential*) nodes.



Reasoning with BNs

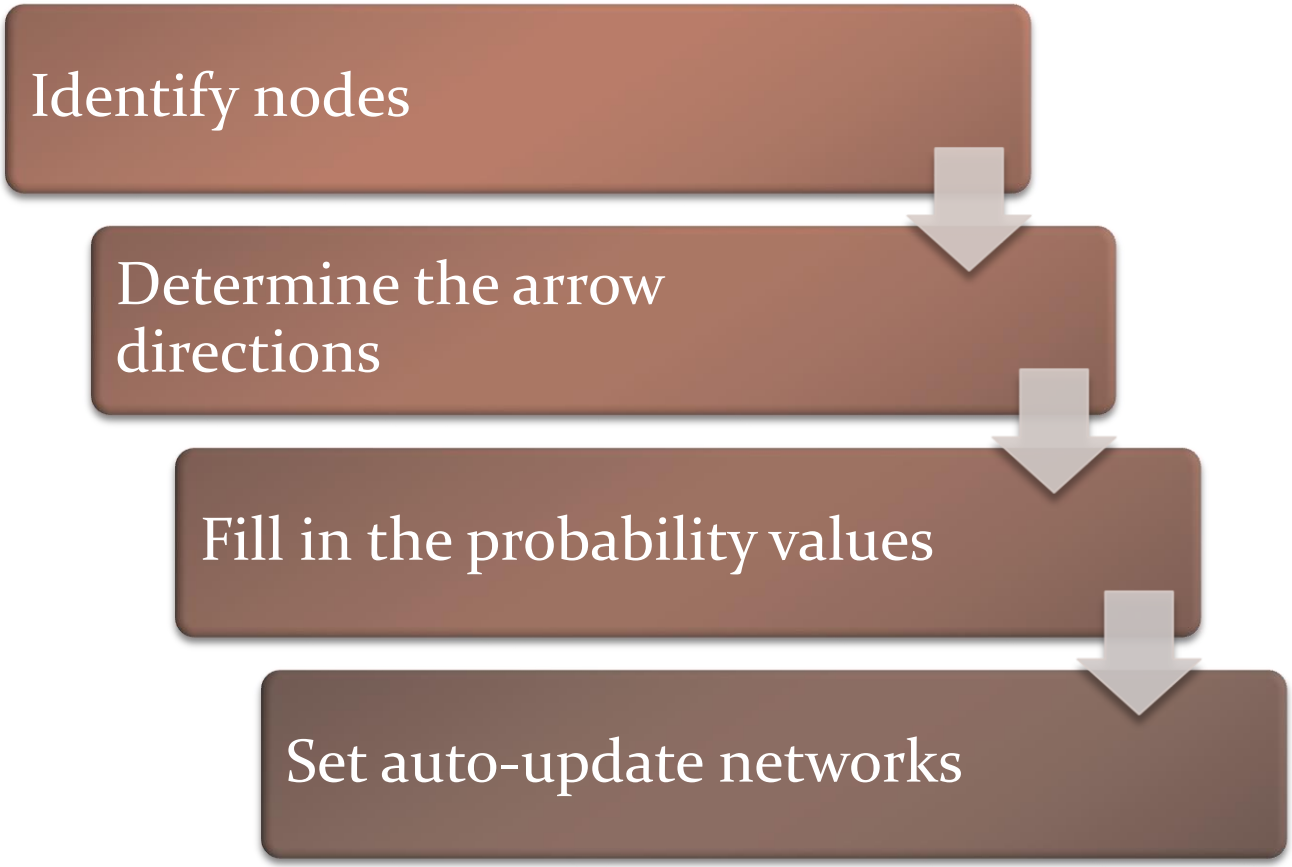
- Predictive Reasoning
  - Reasoning from new information about ***causes*** to new beliefs about ***effects***.
  - The symptoms are *evidence* to infer the cause. That is, to obtain the *posterior probability* of the cause.



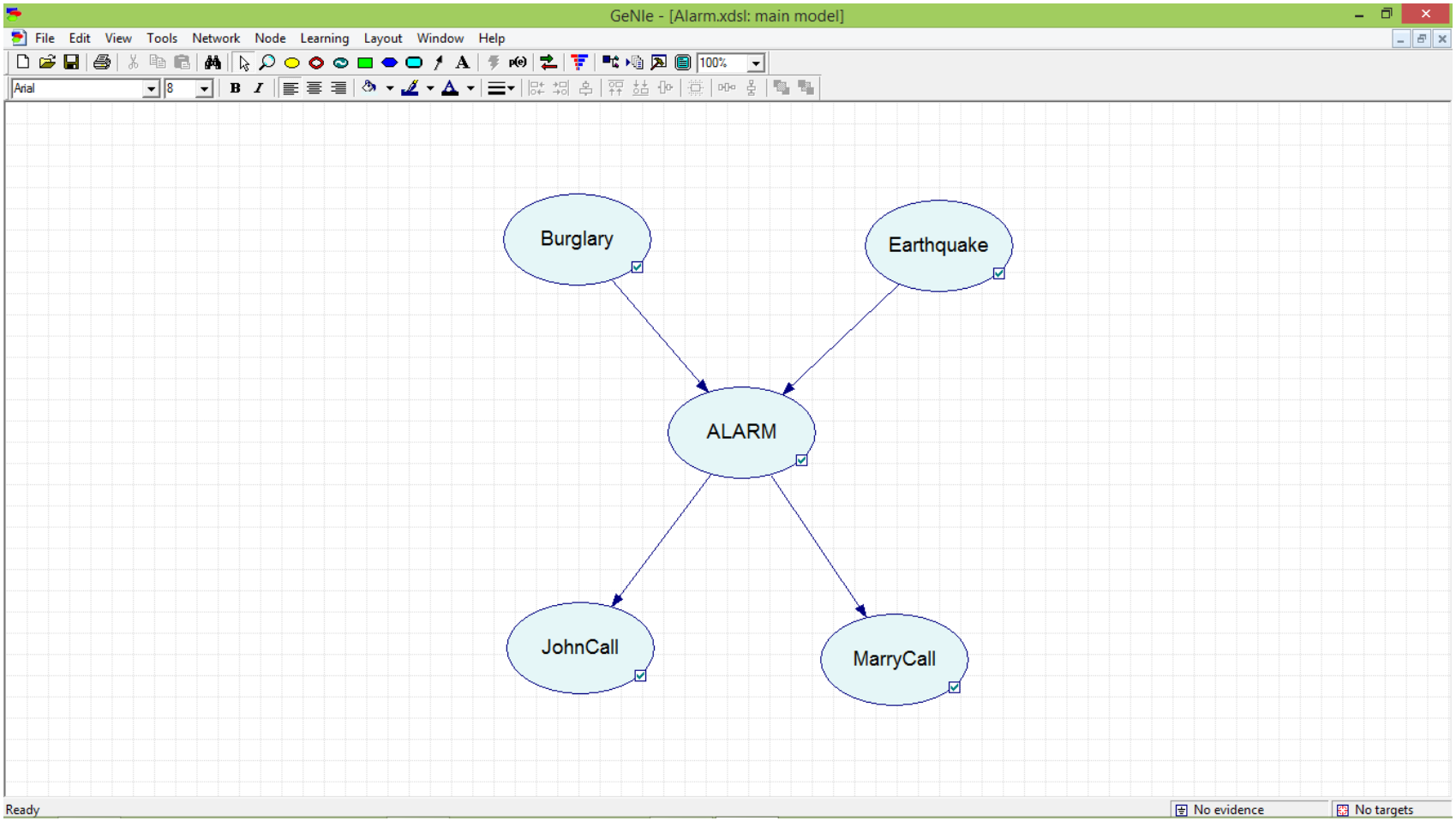
PART 2

(Hands-On: Creating the Alarm BN)

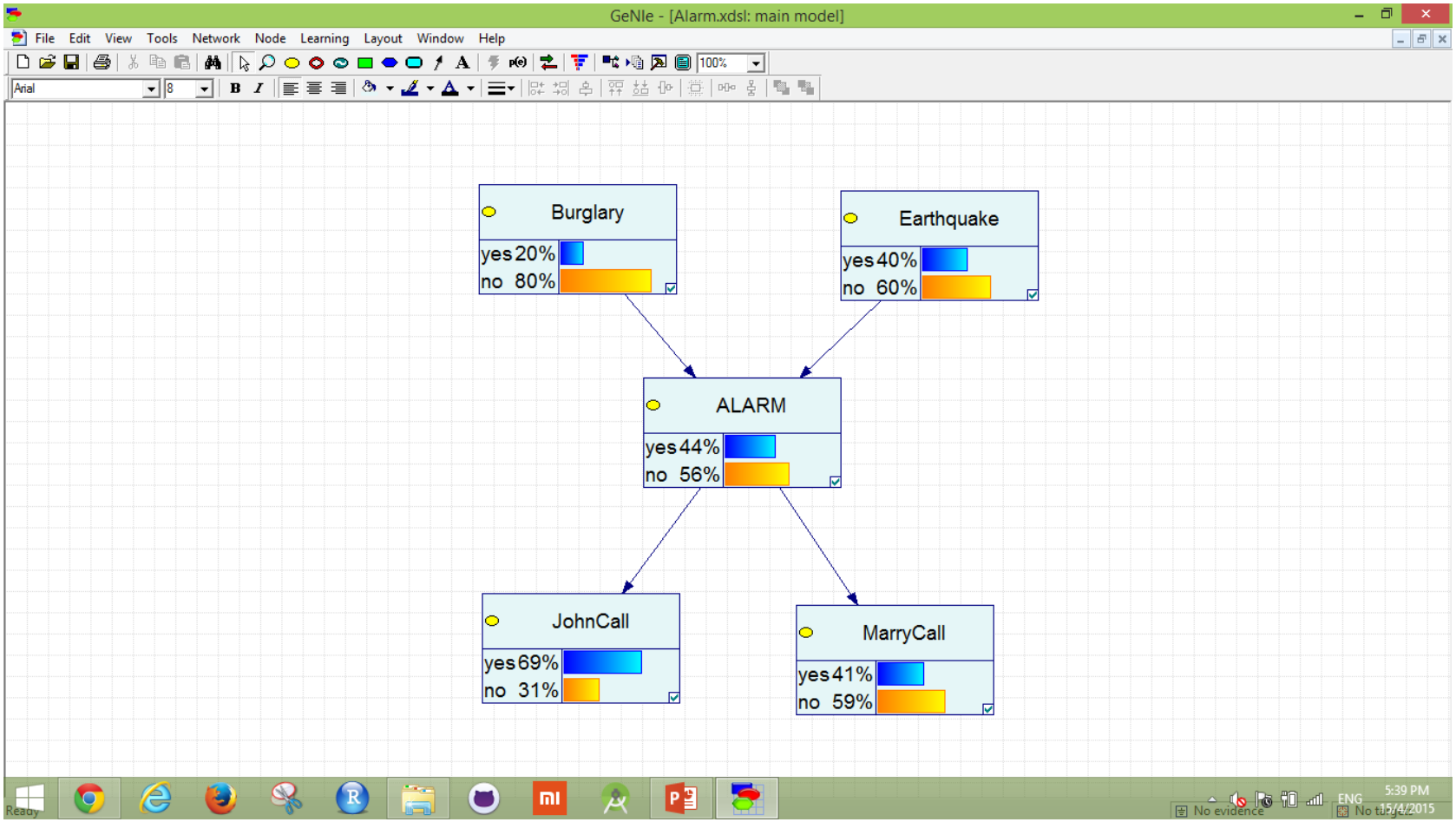
Steps to Create the Alarm BN



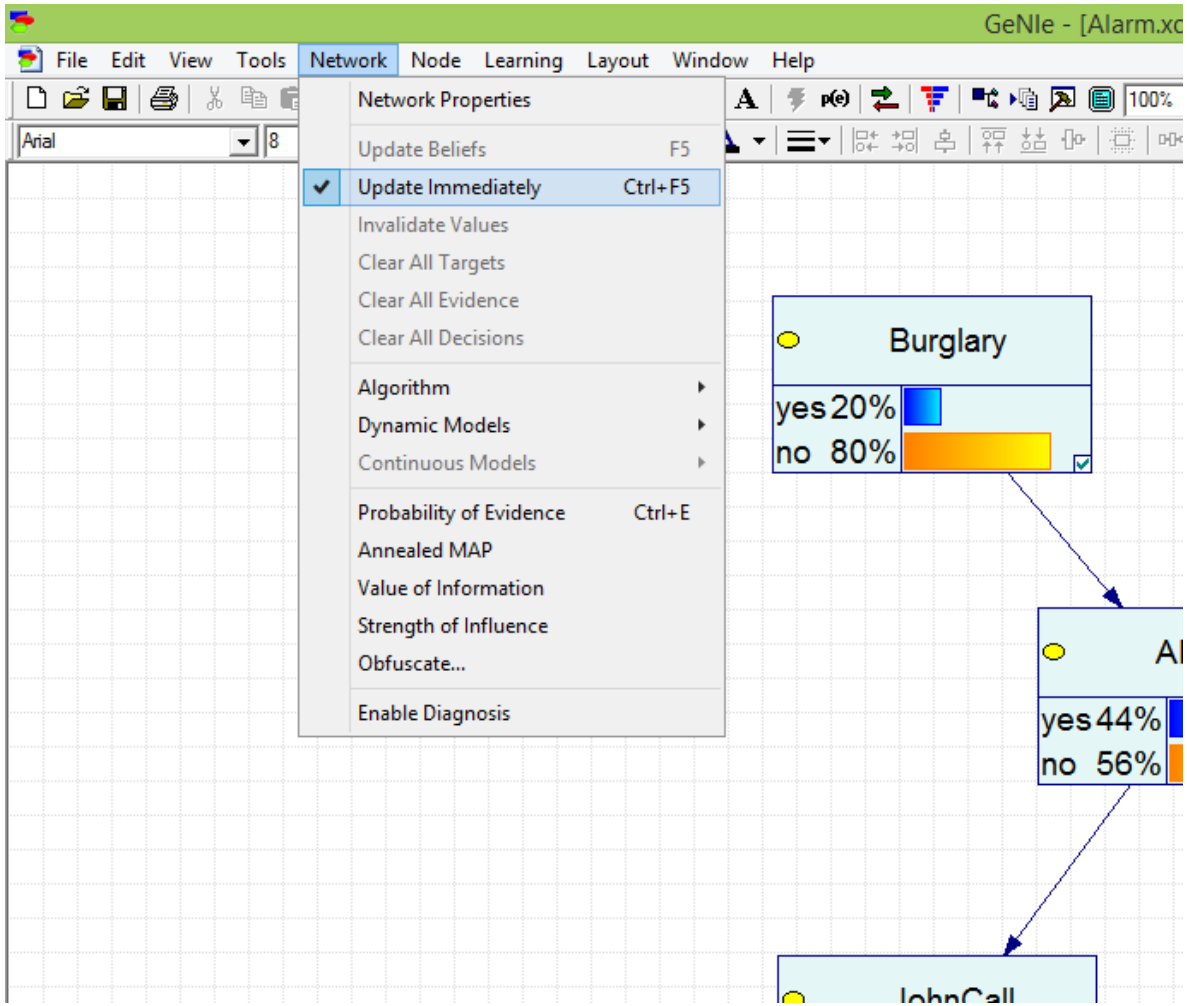
Hands-On: Create the Structure



Hands-On: Specifying the Probability



Hands-On: Auto Update Network



Hands-On: Answering Queries

- **Query 1**: Who has the highest chance to call you first if burglary happens? We don't know whether earthquake happens.
- **Query 2**: If burglary and earthquake does not happen, who will still call you?
- **Query 3**: If you know for sure that the alarm has been triggered, whose call is more important to you? WHY?.
- **Query 4**: If John calls but not Marry, what is the chance that burglary happens?
- **Query 5**: If the alarm is triggered, does it matter if I don't pick up John's call?