Application of Bayesian Networks for Autonomic NGN Management

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Outline

- Introduction
- Research Challenges
- Proposed Approach
- Implementation Details
- Case studies
- BT Internship
- Conclusion
Introduction

- **Communication networks**
  - Earlier: Stand-alone networks
  - Present: Converged network, NGN

- **Network Management Systems**
  - Ensures smooth running of network/services
  - Controls operational cost
  - Increases availability and QoS
  - Improves revenues

- **Issues/Problems**
  - Heterogeneity: Architecture, Mgmt. data, QoS needs
  - Optimising utilisation and guaranteeing QoS: conflicting goals
  - Increased classes of service, real-time constraints
  - Intelligent mechanisms for QoS provisioning
  - Autonomic, Dynamic and Scalable solutions
NGN Architecture

- Core network – IP-based dedicated network over WDM
- Access network – fixed, wireless, mobile
- Edge network – Call Admission Control function for QoS
- Converged service between fixed and mobile
- End to end quality of service (MPLS)
Challenges and Solutions

CHALLENGES
- Network Modelling
- Data Analysis
- Distributed Monitoring
- Real-time Management
- Autonomic Behaviour

CRITERIA
- Complexity
- Speed
- Scalability
- Modularity
- Practicality

SOLUTIONS
- Neural Networks
- SVM
- Bayesian Networks
- Genetic Algorithm
- CBR

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What is a Bayesian Network?

- Flexible and intuitive Machine Learning approach
- Graphical structure to represent knowledge about uncertain variables
- Learning features
  - Structural: PC & NPC algorithms
  - Parameter: EM algorithm
  - Sequential: Adaptation algorithm
- Belief Propagation: estimation of probability of unobserved nodes
- Reasoning: Predictive and Diagnostic
- Decision making: using Influence Diagrams
- Efficient data Classification tool

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Proposed Framework

Feature Selection
Discretise Variables
Structural Learning
Parameter Learning
Model Validation
Model accurate?
Yes
Decision Making
Prediction

Netwok Management System
SLA Monitor
MIB Monitor
Config Data
Mgmt. Data

Intelligent Control Decisions
Decision Support System
Policy Engine
BN

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Implementation Details

**Theoretical Framework**

- To consider the desired objectives of the NGN (e.g. QoS metrics)
  - Delay
  - Throughput
  - Packet loss
  - Jitter
- To apply the following algorithms to realise the BN-based solution
  - Structural learning: PC and NPC algorithms
  - Parameter learning: EM algorithm
  - Sequential learning: Adaptation algorithm
  - Belief Updating: Message Passing Algorithm

**Simulation Framework**

- Network simulators
  - Opnet Modeler 16
  - NCTUns 5.0
- BN modelling software
  - Hugin Researcher 7.3
- Development environment
  - Windows XP and Fedora 10
  - MS Visual Studio 2008
Case Study (Admission Control)

Network Topology

BN Model

Delay Prediction Accuracy

Prediction Accuracy variation (with time)

Case Study (Energy Aware NM²)

Network Topology

BN Model

Router Port Utilisation

Energy savings achieved


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Comparative Study (BN v/s NN$^3$)

Framework for a single router

BN Model

NN Model

Prediction accuracy comparison


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Distributed BN scenario

Centralised BN Model

Distributed BN Model (MEBN)

Multiple router scenario

CPT Size (for 3 BNs) = 280 * 3 = 840

CPT Size (for combined BN) = 1340

Comparison

Prediction accuracy was better for the centralized case

However, computational speed, storage requirements and scalability were the positive aspects of the distributed case

Internship at British Telecom

- **Motivation**
  - Successful implementation of BN in simulated scenarios
  - Need for validation of the proposed solution
  - Reply to the criticism of lack of real data and solution practicality
  - Availability of real data from BT’s 21CN monitoring systems
  - Opportunity to work with a reputed telecom market leader

- **Research problem**
  - Prediction of link failures
  - Already some notable research using Association Rule mining
  - To explore ways to formulate the prediction problem through BN

- **Work done**
  - Spent 3 weeks with the Innovate and Design Division at BT
  - Identified the type of network elements in CP, Access and Core
  - Outputs: BN-based prediction model, research papers (in progress)
Future work: Meshed Network

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Future work: Mathematical Model

We define an entity to be our BN model for a single edge router pair (namely $IR_x - ER_x$, where $x = 1, 2, ..., N$).

For generality we assume the number of entities to be $N$, named $Y_1$ to $Y_n$. Then the joint probability of the overall domain (which is composed of multiple entities) will be:

$$P(y_1, y_2, ..., y_N) = P(y_1) \times P(y_2 | y_1), ..., \times P(y_N | y_1, y_2, ..., y_{N-1})$$

$$= \prod_j P(y_j | y_1, ..., y_{j-1}), \text{ where } j = 1, 2, ..., N$$

(1)

where from previous Eq.,

$$P(y_j) = \prod_i P(x_{ij} | \text{Parents } (X_{ij}))$$

where $X_{ij}$ is the $i^{th}$ node of BN corresponding to the $j^{th}$ entity in the MEBN.

Finally applying the reasoning that, not every entity is dependent on another, we can define the joint probability as:

$$P(y_1, y_2, ..., y_N) = \prod_j P(y_j | \text{Parents } (Y_j))$$

(2)

where Parents $(Y_j) \subseteq \{y_j | y_1, ..., y_{j-1}\}$.

In the special case when all the entities are independent (i.e. no child and parent relationship exists in the MEBN) then Eq. (2) becomes:

$$P(y_1, y_2, ..., y_N) = \prod_j P(y_j)$$

$$= \prod_j \left( \prod_i P(x_{ij} | \text{Parents } (X_{ij})) \right)$$

(3)

Eq. (3) characterises a special case of MEBN and is the mathematical foundation on which we base our experiments in the simulation environment. The following slide provides the details of the simulation environment which was considered for our experiments and results.
Conclusion

- BN have been shown to effectively model network scenarios and achieve desired management goals

- Case studies: CAC, Energy-aware traffic engineering, comparison with NN, distributed BN

- Offline modelling, cross validation and prediction results presented

- BT Internship: Test and validate BN solution on real data for link failure prediction
Publications

Conference papers


Abstracts / Posters


THANK YOU