Telecommunication network planning and software development

Paper:

Network Structure Optimization by Using GA (Genetic Algorithm)

T.B.Le, H.B.Tran, H.T.Tran, V.Q.Nguyen, D.T.Duy, D.V.Dinh,
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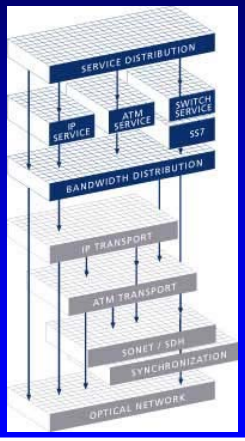
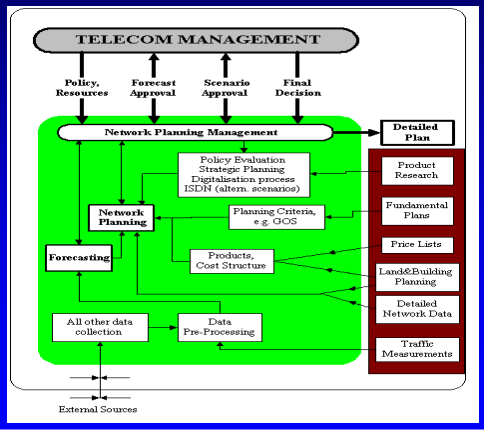
Contents

Challanges to Planners

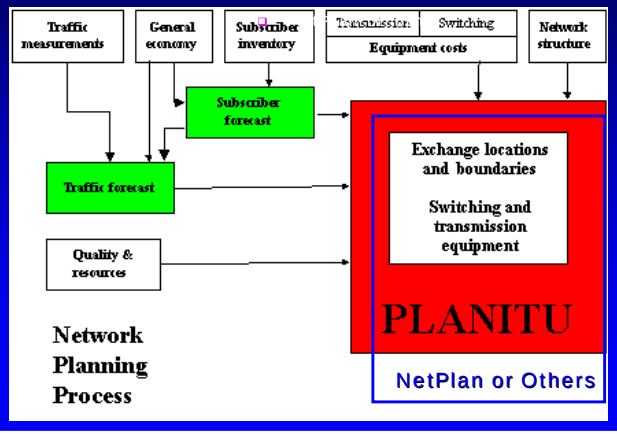
- Services
  - ✓ Service distributions
  - ✓ PSTN, IP, Frame relay, and ATM services
  - ✓ Bandwidth distribution
- Network technologies
  - ✓ PSTN
  - ✓ IP over ATM, IP over SDH/WDM
  - ✓ Frame Relay, ATM
  - ✓ SONET/SDH
  - ✓ WDM/DWDM



Network Planning: Functions and Interfaces



Network Planning Process



2. Telephone Services Demand and Traffic Forecasting

- Contents
  - ✓ Basic concepts
  - ✓ Recommended forecasting methods
  - ✓ Forecating for a rural network
    - Subscriber Forecast per Village
    - Exponential Logistic Model
    - Problems
    - Solution
    - Computer algorithm

Basic Concepts

- Type of Forecasts
  - ✓ Overall Forecast vs. Detailed Forecast
- Data needed for planning
  - ✓ Subscriber distribution
  - ✓ Traffic
- Planning Periods
  - ✓ Customers Apparatus Requirements 1-2 years
  - ✓ Exchange Switching Equipment Provisioning 3-4 years
  - ✓ Local Lines Planning 6-10 years
  - ✓ Ducts 10-15 years
  - ✓ Planning and Construction of Buildings 10-20 years
  - ✓ Site Acquisition and Disposal Policy up to 50 years

Recommended Forecasting Methods

Methodology	Name
Telephone services demand forecasting	Econometric (E) Logistic (L) L-E
Telephone services traffic forecasting	Kruithof Advanced Kruithof
Non-voice services demand and traffic forecasting	ITU-T procedure Logistic (L)

Forecasting for a Rural Network

- Subscriber Forecast per Village
  - ✓ Exponential Logistic Model

$$D_V = Y_V \cdot DMAX_V \qquad Y_V = \frac{1}{\left(1 + e^{-C_V (T - T_0)}\right)^{1/M_V}}$$

Where,

P	= Population
$DMAX$	= Maximum penetration = saturation limit
Y	= Ratio penetration to maximum penetration
D	= Penetration
M	= Curve constant (density forecast)
C	= " " " "
v	= Village no.
(T)	= point of time
(0)	= Present time

Forecasting for a Rural Network *(Cont.)*

- Exponential Logistic Model
  - ✓ Calculation procedure

1. $Y_V(0) = \frac{N_V(0) + L_V(0)}{P_V(0)} / DMAX_V \qquad Y_V(-5) = \frac{N_V(-5) + L_V(-5)}{P_V(-5)} / DMAX_V$
2. $T = 0, \quad Y = Y_V(0)$
3. $T = -5, \quad Y = Y_V(-5)$

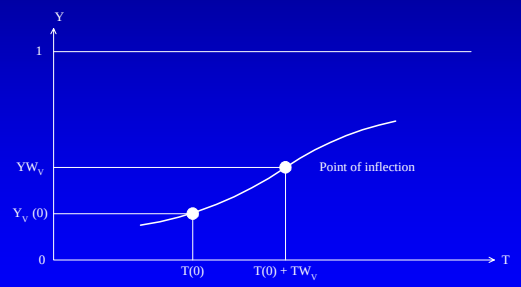
$$M_V : M_V = -\frac{\ln 2}{\ln Y_V(0)} \qquad C_V : C_V = 1/5 \cdot \ln\left(\left(Y_V(-5)\right)^{-M_V} - 1\right)$$

Constants calculation

4. T= 5, 10, 15 $\quad Y_V(5),\ Y_V(10),\ Y_V(15)$
5. $TW_V = -\frac{\ln M_V}{C_V}$ — *Distance in years from T = 0 to point of inflection*
6. $YW_V = \frac{1}{(M_V + 1)^{1/M_V}}$ — *Height of curve at point of inflection*
7. $D_V(T) = Y_V(T) \cdot DMAX_V(T)$

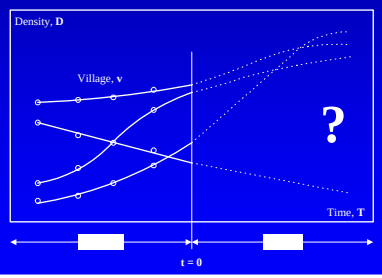
Forecasting for a Rural Network *(Cont.)*

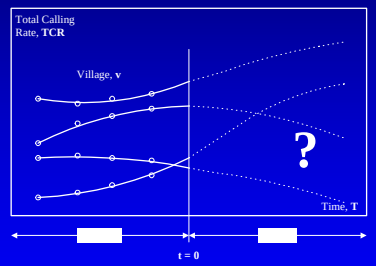
- Exponential Logistic Model
  - ✓ Graph presentation



Forecasting for a Rural Network *(Cont.)*

- Problems
  - ✓ Huge number of villages
  - ✓ Great differences between villages





Forecasting for a Rural Network *(Cont.)*

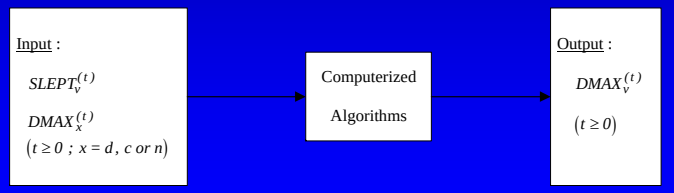
- Solution
  - ✓ Categorizing villages by SLEPT variables
    - S = Size of population
    - L = Level
    - E = Socio-Economic type
    - P = Private economic level
    - T = Population development trend
  - ✓ Planners should initiate appropriately the SLEPT variables for their country (*See Hanam case study later on*)
  - ✓ Using SLEPT variables to calculate relevant forecasting parameters
    - future village density saturation limit $DMAX_v^{(t)}$
    - future calling rate $TCR_v^{(t)}$
    - future proportion of originating traffic $PO_v^{(t)}$
    - future proportion of internal traffic $PI_v^{(t)}$

Forecasting for a Rural Network *(Cont.)*

- Computer Algorithm
  - ✓ To calculate saturation levels per village $DMAX_v^{(t)}$

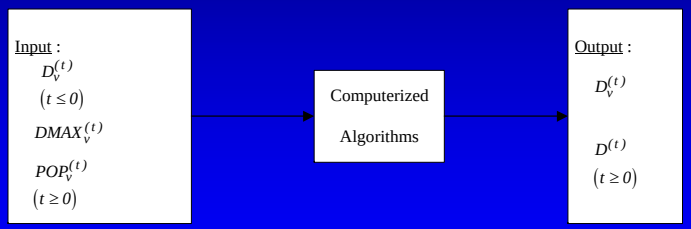
$$DMAX_v^{(t)} = DMAX_x^{(t)} \cdot FDS_v^{(t)} \cdot FDL_v^{(t)} \cdot FDE_v^{(t)} \cdot FDP_v^{(t)} \cdot FDT_v^{(t)}$$

  - ✓ Procedure



Forecasting for a Rural Network *(Cont.)*

- Computer Algorithm
  - ✓ To calculate future densities per village $D_v^{(t)}$



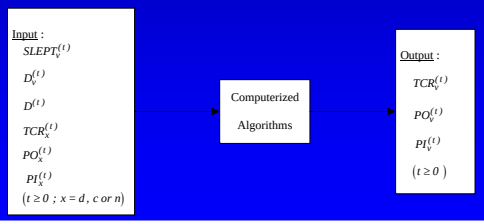
Forecasting for a Rural Network *(Cont.)*

- Computer Algorithm
  - ✓ To calculate future Calling Rate/Orig./Internal traffic per village

$$PO_v^{(t)} = PO_x^{(t)} \cdot FOS_v^{(t)} \cdot FOL_v^{(t)} \cdot FOE_v^{(t)} \cdot FOP_v^{(t)} \cdot FOT_v^{(t)} \cdot FOD_v^{(t)}$$

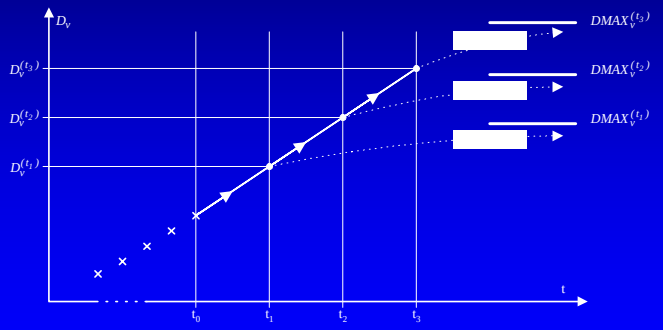
$$TCR_v^{(t)} = TCR_x^{(t)} \cdot FTS_v^{(t)} \cdot FTL_v^{(t)} \cdot FTE_v^{(t)} \cdot FTP_v^{(t)} \cdot FTT_v^{(t)} \cdot FTD_v^{(t)}$$

$$PI_v^{(t)} = PI_x^{(t)} \cdot FIS_v^{(t)} \cdot FIL_v^{(t)} \cdot FIE_v^{(t)} \cdot FIP_v^{(t)} \cdot FIT_v^{(t)} \cdot FID_v^{(t)}$$



Forecasting for a Rural Network *(Cont.)*

- $DMAX_v^{(t)}$ Illustration



Forecasting for a Rural Network *(Cont.)*

- From SLEPT to Fxx (FDS, ...)
  - ✓ General influence on TCR, PO, PI and DMAX by S, L, E, P, t and D.

On / By	TCR	PO	PI	DMAX
S	5	2	1	1
L	1	1	2	2
E	2	3	3	3
P	3	5	4	4
T	6	4	5	5
D	4	6	6	Not applicable

Note:

"1" means the strongest influence, "2" means the next to strongest influence, etc.

Forecasting for a Rural Network *(Cont.)*

- From SLEPT to Fxx (FDS, ...)
  - ✓ Algorithm

$$FYQ = \frac{|B| \cdot CB + \left(Z + CZ\sqrt{Q} - Z + CZ\sqrt{\bar{Q}} \right) \cdot TB}{|B| \cdot CB}$$

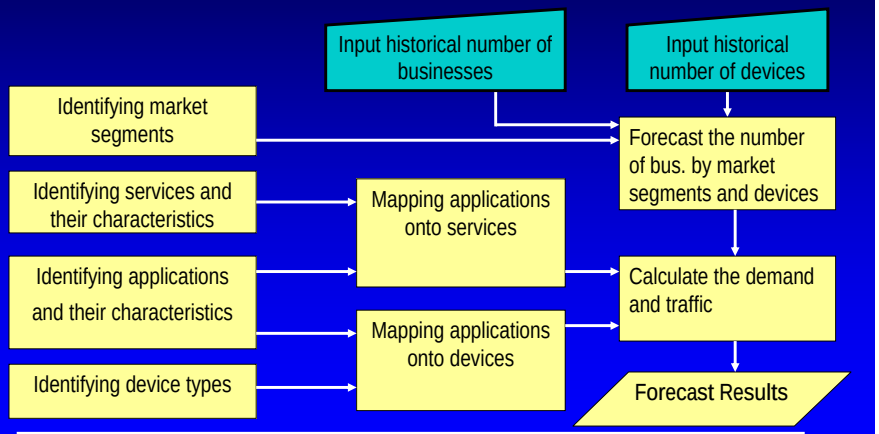
Where,

*Y = letter **D**, **T**, **O** or **I** (representing **DMAX**, **TCR**, **PO** or **PI**);*
*Q = **S**, **L**, **E**, **P**, **T** or **D**; (Q is interpreted as a letter in the name "FYQ", otherwise as a variable)*
*$\bar{Q}$ = average value of **S**, **L**, **E** ,**P**, **T** or **D**;*
B = curve steepness parameter; Z = curve shape parameter;
*CB = scale constant for **B**; CZ = scale constant for **Z**;*
*TB = **+1** for positive **B**-values, **-1** for negative **B**-values;*
*|B| = absolute value of **B**.*

3. Non-Voice Services Demand and Traffic Forecasting

- Contents
  - ✓ Overall process
  - ✓ Identifying market segments
  - ✓ Identifying services and their characteristics
  - ✓ Mapping applications onto services
  - ✓ Forecasting methods
  - ✓ Forecasting

Overall Process



Identifying Market Segments

- Business companies are classified into the following market segments:
  - ✓ *Large: >1000 employees*
  - ✓ *Medium: 100-1000 employees*
  - ✓ *Small: <100 employees*
  - ✓ *Residential*
  - ✓ *Other organizations*

Identifying Services and Their Characteristics

- Each service has a different set of characteristics, for example:
  - ✓ Link activity rate
  - ✓ Transmission rate
  - ✓ Average holding time
  - ✓ etc.

Mapping Applications onto Services

- An application can run on several services
- The proportion of application used in services changes over time
- Therefore, it is necessary to map between applications and services

Forecasting Methods

- Linear model is used for forecasting the number of businesses and locations
- Logistic model is used for forecasting the number of devices by device type
- No other forecasting methods can be used

Forecasting

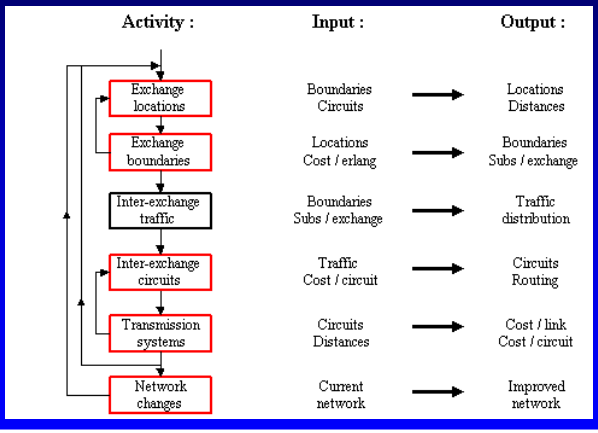
- Estimates the proportion of applications used in services
- Forecasts the number of businesses
- Forecasts the number of devices
- Calculates the demand and traffic by application and service

4. PSTN Dimensioning and Optimization

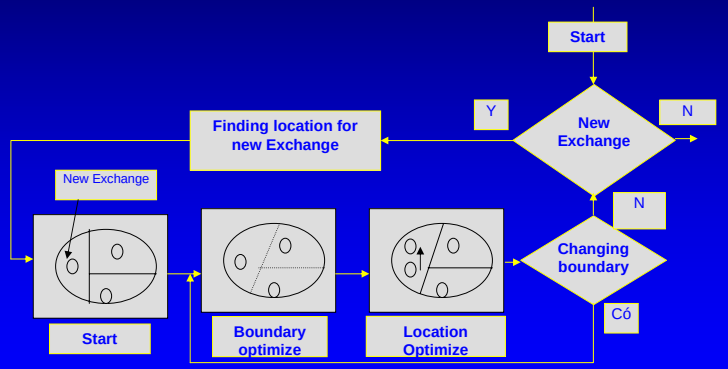
- Contents(*)
  - ✓ Dimensioning process
  - ✓ Network structure optimization
  - ✓ Optimization of circuits on high-usage route
  - ✓ Calculation of overflows traffic
    - Full availability case
    - Restricted availability case

(*) It is for local networks or long distance networks

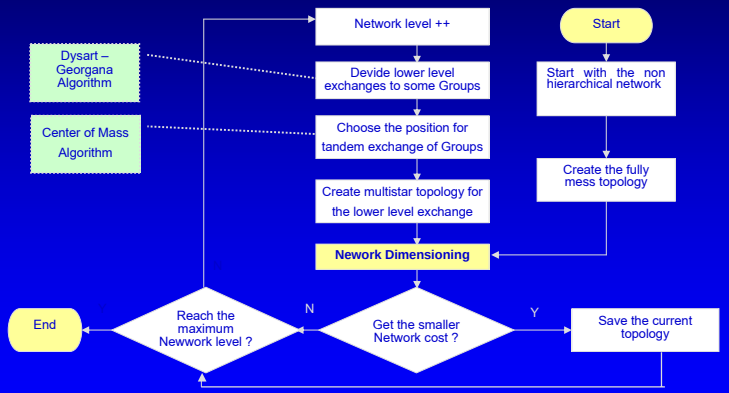
Dimensioning Process



4. PSTN Dimensioning and Optimization



4. PSTN Dimensioning and Optimization

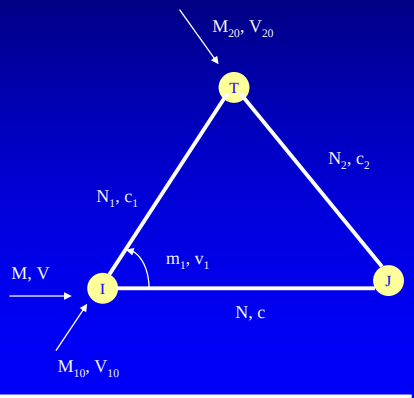


Optimization of Circuits on High-Usage Route

- Configuration of Study
  - ✓ 3 exchanges
    - Local exchages: I and J
    - Transit/Tandem: T

Denote:

M,V	*mean and variance of offered traffic to route i->j*
M_{10},V_{10}	*mean and variance of traffic offered to route i->T , not including the overflow traffic from route i->j*
M_{20},V_{20}	*ditto for route T->J*
c,c_1,c_2	*cost of one additional circuit on route ,, and , resp.*



Optimization of Circuits on H Route (Cont.)

- Problem Formulation
  - ✓ Total traffic offered to the overflow routes

$$M_1 = M_{10} + m(N) \qquad M_2 = M_{20} + m(N)$$

$$V_1 = V_{10} + v(N) \qquad V_2 = V_{20} + v(N)$$

  - ✓ It is to determine N so that the resulting cost is minimised

$$C(N) = c \cdot N + c_1 \cdot N_1 + c_2 \cdot N_2$$

Denote:

m(N) and v(N) as mean and variance of the overflow traffic from route

N as number of circuits on route i->j

N_1 and N_2 are the circuits on the overflow routes

Optimization of Circuits on H Route (Cont.)

- Solution
  - Equate the derivative, with respect to N, to zero

$$c + c_1 \cdot \frac{\partial N_1}{\partial N} + c_2 \cdot \frac{\partial N_2}{\partial N} = 0$$

  - For a given GoS $N_i = N_i(M_i, V_i)$
  - Let $\Theta_i = \frac{V_i}{M_i}$ so $N_i = N_i(M_i, \Theta_i)$
  - Take the deriviation of N $\frac{\partial N_i}{\partial N} = \frac{\partial N_i}{\partial M_i} \cdot \frac{\partial M_i}{\partial N} + \frac{\partial N_i}{\partial \Theta_i} \cdot \frac{\partial \Theta_i}{\partial N}$
  - It is well known that $M_i = M_{i0} + m$ $\Theta_i = \frac{V_{i0} + v}{M_{i0} + m}$

Optimization of Circuits on H Route (Cont.)

- Solution (Cont.)
  - Then, $\frac{\partial M_i}{\partial N} = \frac{\partial m}{\partial N}$ $\frac{\partial \Theta_i}{\partial N} = \frac{\frac{\partial v}{\partial N} - \Theta_i \cdot \frac{\partial m}{\partial N}}{M_i}$
  - Get approximately $\frac{\partial N_1}{\partial N} \approx \frac{\partial N_1}{\partial M_1} \cdot \frac{\partial m}{\partial N}$ $\frac{\partial N_2}{\partial N} \approx \frac{\partial N_2}{\partial M_2} \cdot \frac{\partial m}{\partial N}$
  - Inserting these derivatives in the derivative of the cost function

$$-\frac{\partial m}{\partial N} = \frac{c}{c_1 \cdot \frac{\partial N_1}{\partial M_1} + c_2 \cdot \frac{\partial N_2}{\partial M_2}}$$

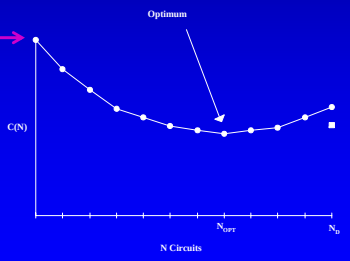
  - Denote $c_1 \cdot \frac{\partial N_1}{\partial M_1} + c_2 \cdot \frac{\partial N_2}{\partial M_2}$ as C_T
    - *It is the cost of carrying 1 Erl. Over transit route*

Optimization of Circuits on H Route (Cont.)

- Solution (Cont.)
  - Original cost equation can thus be re-written

$$C(N) = c \cdot N + m(N) \cdot C_T \qquad (1)$$

  - Graph presentation
  - Overflow traffic m(N)
    - If, M=V,
      - Use the Wilkinson formular
    - If M ≠ V,
      - Find N*, A*
      - Then use the Wilkinson formular



Wilkinson Formula

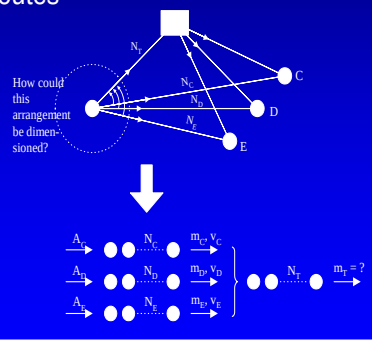
- Primary Routes

$$m = A \cdot E_N(A)$$

$$v = m \cdot \left(1 - m + \frac{A}{N + 1 - A + m}\right)$$

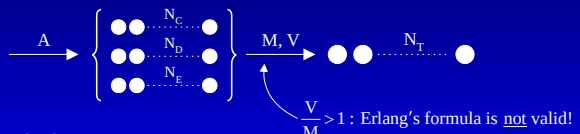
Where $E_N(A) = \frac{\frac{A^N}{N!}}{\sum_{i=0}^{N} \frac{A^i}{i!}}$

- Alternative Routes



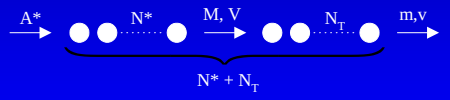
Wilkinson Formula *(Cont.)*

- Problem: over flow traffic is not Poisson



- Solution

Equivelent group



Then $m = A^* \cdot E_{N+N^*}(A^*)$ $\quad v = m \cdot \left(1 - m + \frac{A^*}{N + N^* + 1 - A^* + m}\right)$

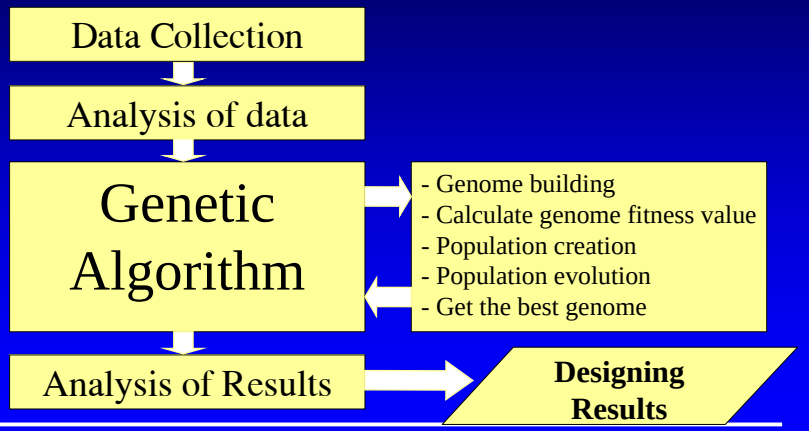
Computer Algorithm

1. Initiate $\frac{\partial N_i}{\partial M_i}$ and calculate C_T for all links
2. Ordering the links to be processed
3. Using Formular 1 to dimension each pair of the links set (previous slides)
4. Update $\frac{\partial N_i}{\partial M_i}$ and C_T
5. Repeat from step 3

5. Access Networks Dimensioning and Optimization

- Implementation Approach
  - ✓ Fiber optic, xDSL and WLL technologies are considered for connecting subscribers
  - ✓ Genetic Algorithm (GA) is used to design access network
  - ✓ Too-stage optimization: determining network topology (by GA) and network dimensioning

Overall Process



GA Concepts

- Optimization by searching the solution space
  - ✓ Given the solution space Ω
  - ✓ Find a specific solution z(ω) subject to given constraints
- Search process based on the principle of natural selection
  - ✓ Reproduction
  - ✓ Crossover
  - ✓ Mutation

→ ***Survival of the fittest***

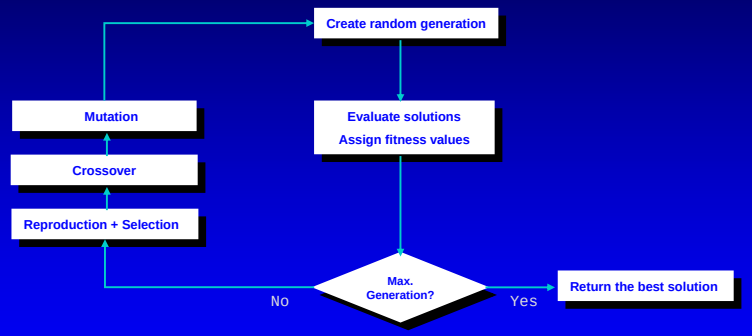
GA Concepts (Cont.)

- Terminologies
  - ✓ Coding of solutions
    - ↗ Gene
    - ↗ Genetic string
  - ✓ Generation
    - ↗ Set of genetic strings that make up the population at a certain time
  - ✓ Fitness of genetic strings
    - ↗ Correlates with the quality of a speciffic solution respective to the object function z(ω)
    - ↗ determines the surviablity of a solution

GA Concepts (Cont.)

- Terminologies
  - ✓ Reproduction
    - ↗ Create a new generation (depend on the fitness value)
  - ✓ Crossover
    - ↗ Change the genes between two genetic strings
  - ✓ Mutation
    - ↗ Change the genes within a genetic string

GA Implementation



Genome Model

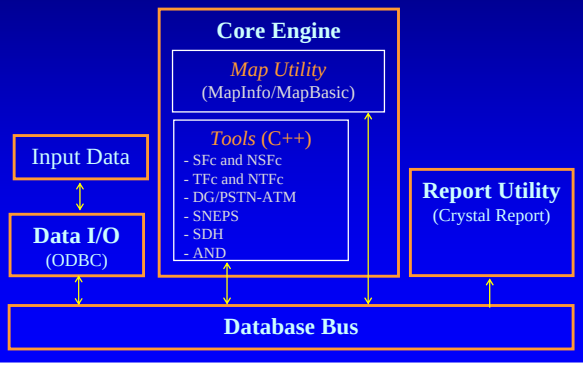
- Each xDSL, FO DLC and WLL node in the network is specific gen
- Network topology is genome
- Genome have composite structure and varying length

Cost Model

- Network Node Cost
  - ✓ Cost of xDSL, DLC node or Base Station equipment
  - ✓ Cost of node construction
  - ✓ Cost of transmission media (include construction cost) from node to parent node
- Subscriber Cost
  - ✓ Cost of subscriber equipment (in the node subscriber connected)
  - ✓ Cost of cable (include construction cost) from subscriber to xDSL, DLC, WLL node or the CO if subscriber is connected directly via cable

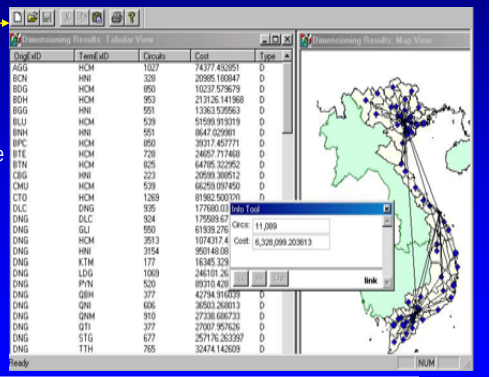
NetPlan Tools Introduction

- Software Architecture



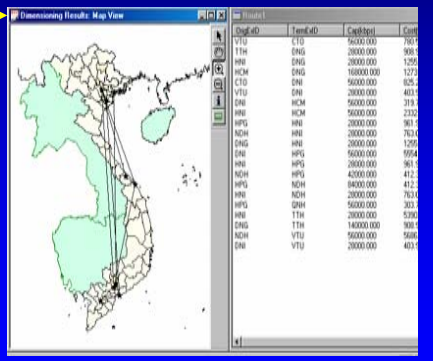
NetPlan Tools Introduction (cont.)

- DG/PSTN: PSTN networks dimensioning tool
  - ✓ GUI: Friendly
  - ✓ Input: any from DB formarts
  - ✓ Features
    - Data input is easy
    - Finding optimal network structure
    - PlanITU similar features



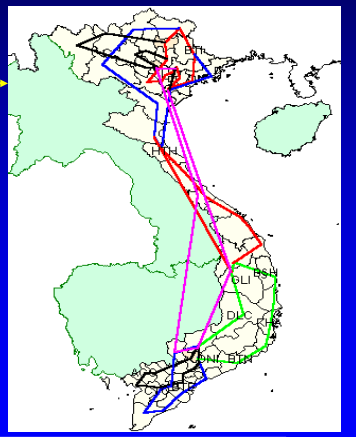
NetPlan Tools Introduction (cont.)

- DG/ATM: ATM networks dimensioning tool
  - ✓ GUI: Friendly
  - ✓ Input: any from DB formarts
  - ✓ Features
    - For all ATM Forum classified services
    - Finding optimal ATM network structure
    - Link capacity calculation
    - Resilience



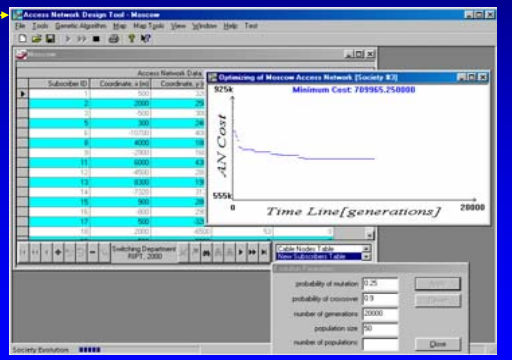
NetPlan Tools Introduction (cont.)

- SDH networks dimensioning tool
  - ✓ GUI: Friendly
  - ✓ Input: any from DB formarts
  - ✓ Features
    - For all ITU classified services
    - Ring topology
    - Details on different levels of mutipllexing
    - Protection



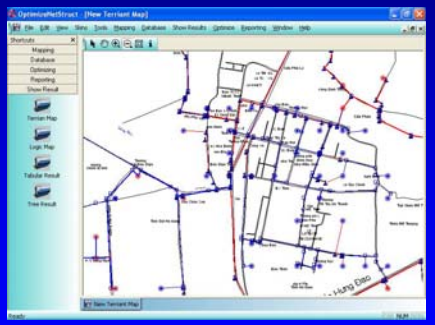
NetPlan Tools Introduction (cont.)

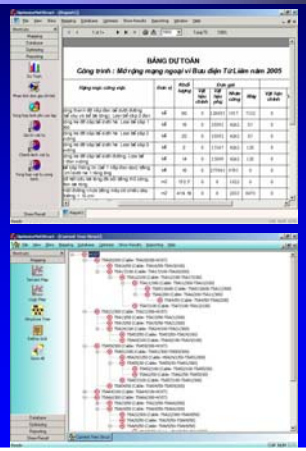
- AND: Access networks design tool
  - ✓ GUI: Friendly
  - ✓ Transmission media
    - Copper / Fiber optic / xDSL
    - WLL
  - ✓ Optimization GA algorithms
    - Simple
    - Steady-state
    - Crowding
    - Incremental
    - Deme (multiple populations)



NetPlan Tools Introduction (cont.)

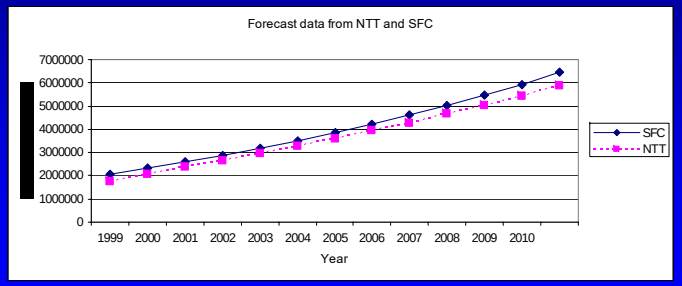
- AND: Map and Data results





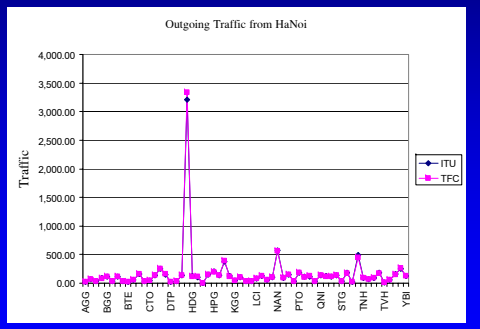
Numerical experiments

- Subscriber forecasting



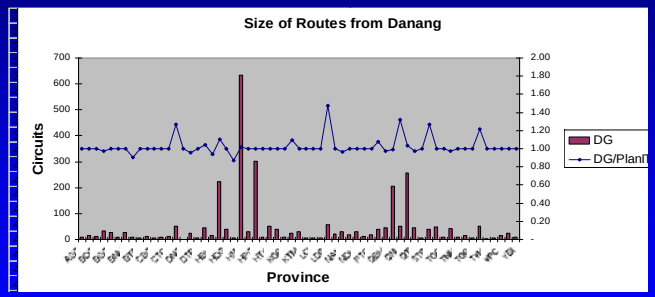
Numerical experiments

- Traffic calculation



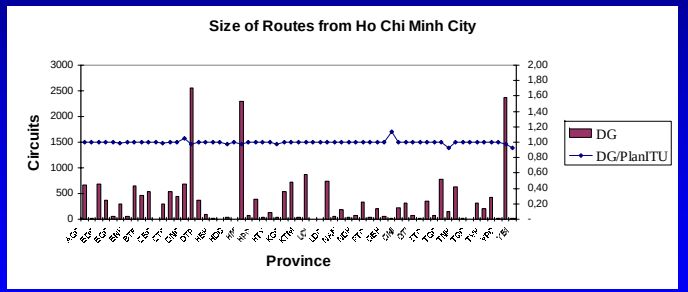
Numerical experiments

- Network Dimensioning



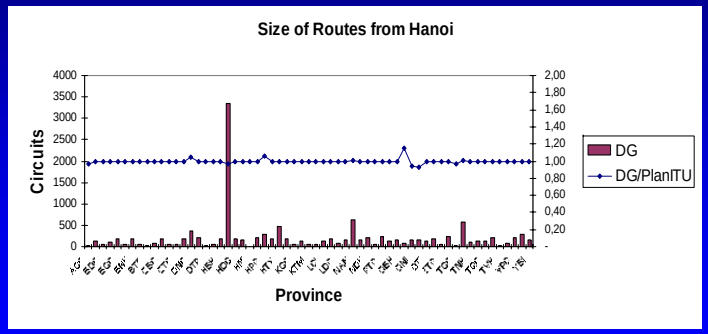
Numerical experiments

- Network Dimensioning



Numerical experiments

- Network Dimensioning



Conclusion

- Network planning is complex problem
- Closely relate to network management and traffic engineering
- Limitation on voice network
- Running time
- Nonvoice Traffic
- Wireless Data network