

Optimal Placement of Different Types of Monitoring Equipment in Transparent Optical Networks

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(D)WDM Network Model

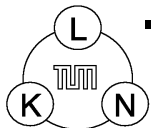
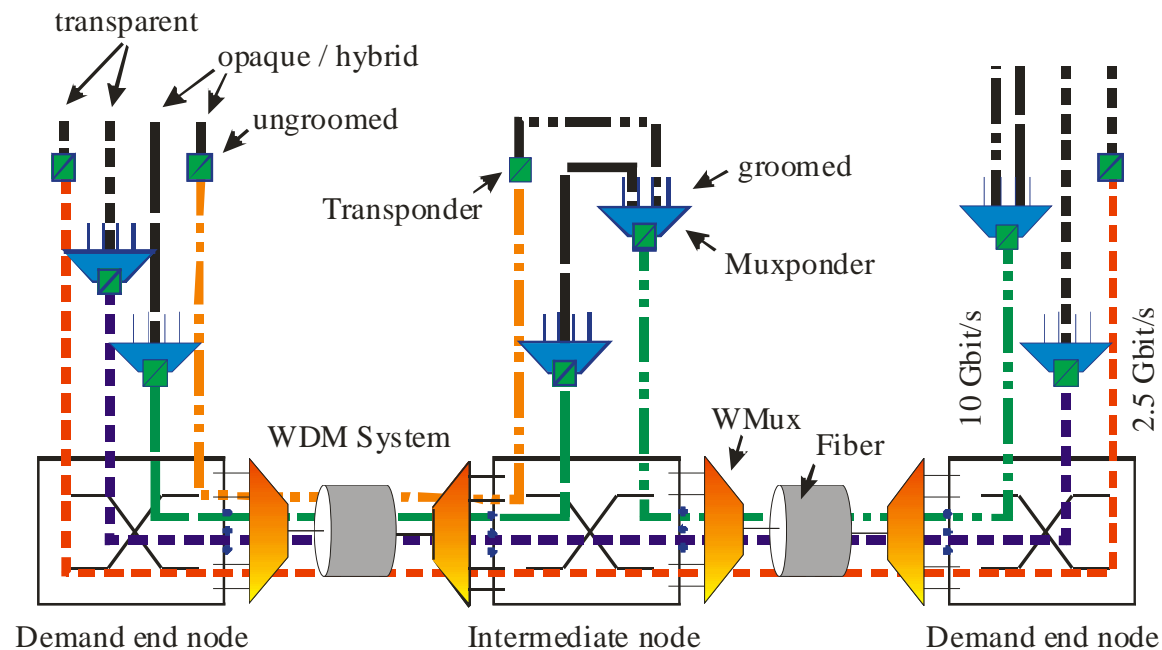
- All-optical transparent
 - no intermediate grooming
 - optical bypass using, e.g., optical cross-connect (OXC) or optical patch panel (OPP)
- Opaque
 - intermediate grooming using O/E/O conversion
 - no optical bypass
- Hybrid
 - intermediate grooming
 - optical bypass using OXC / OADM / OPP

Signal Layer

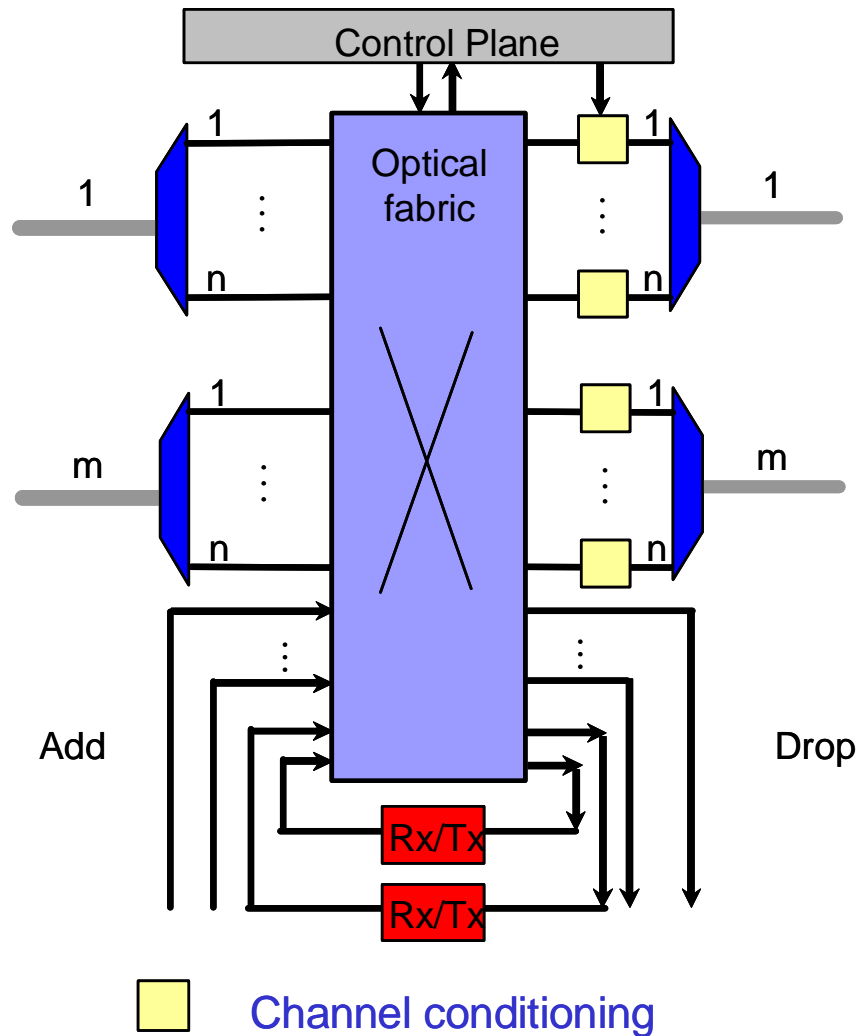
- Transponder 
- Muxponder 
- OCP 

DWDM layer

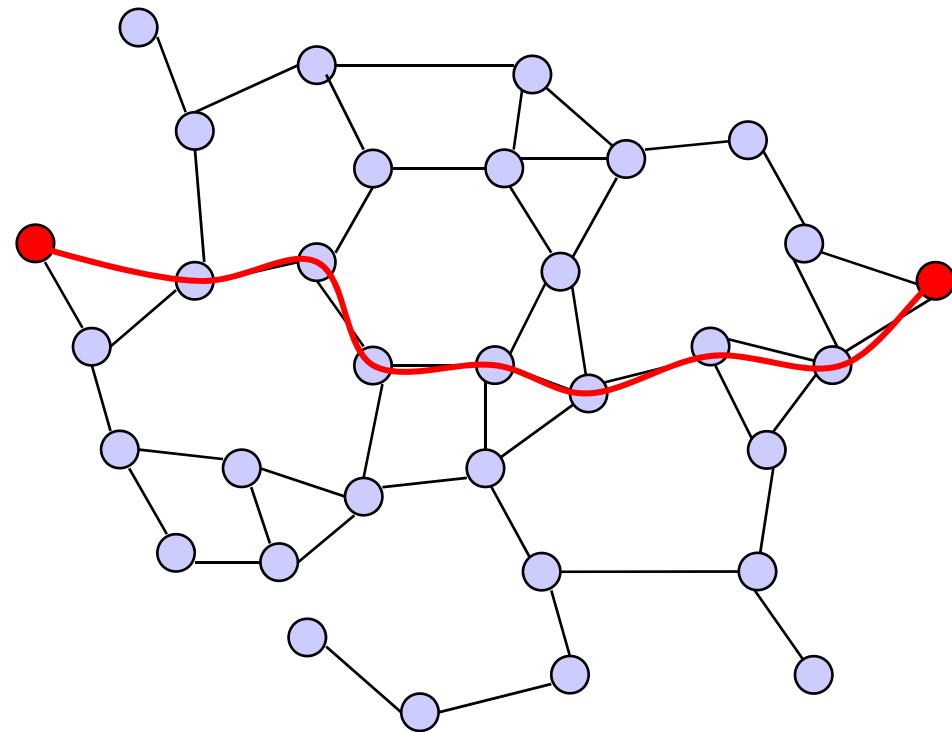
- WMux



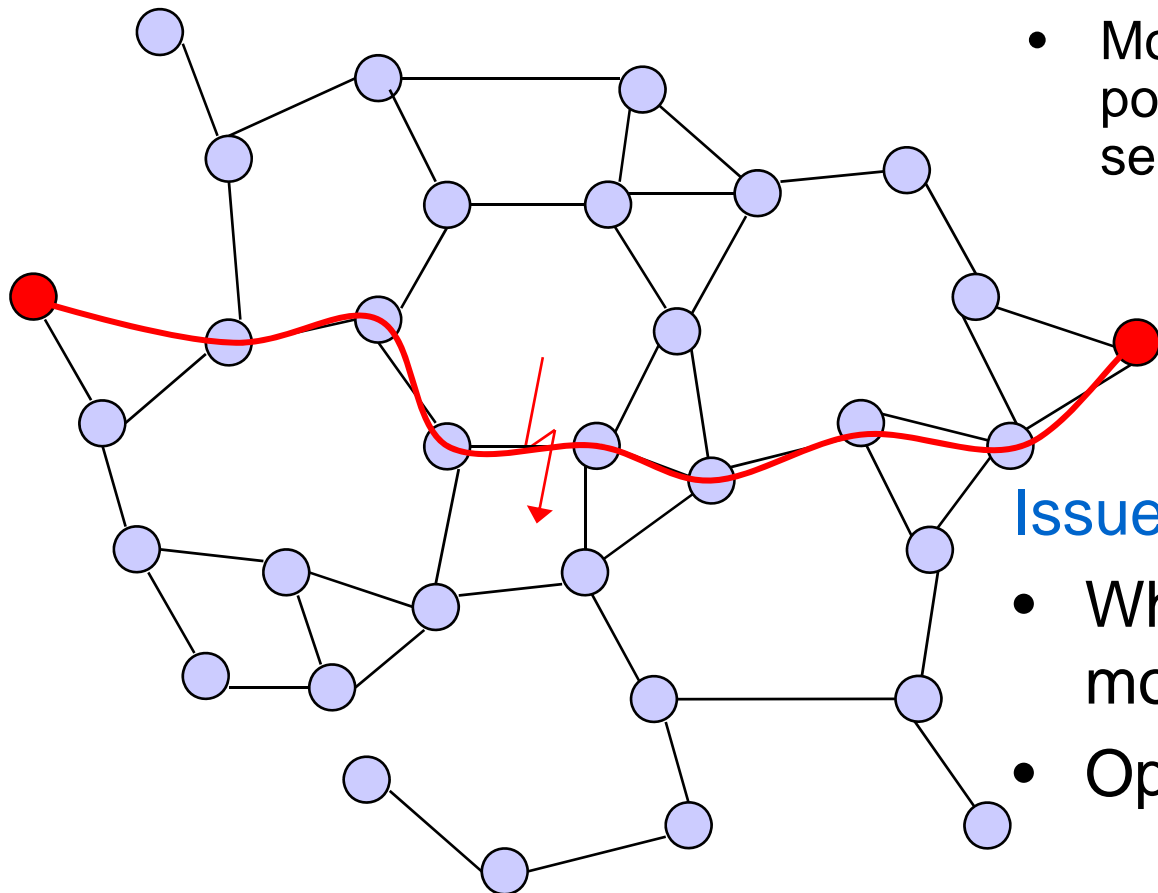
Why is Monitoring a Challenge?



- No O/E/O-conversion at intermediate nodes in transparent networks



Why is Monitoring a Challenge?



Solution:

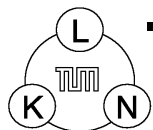
- Monitoring of a tapped portion of the signal at selected nodes

Issues:

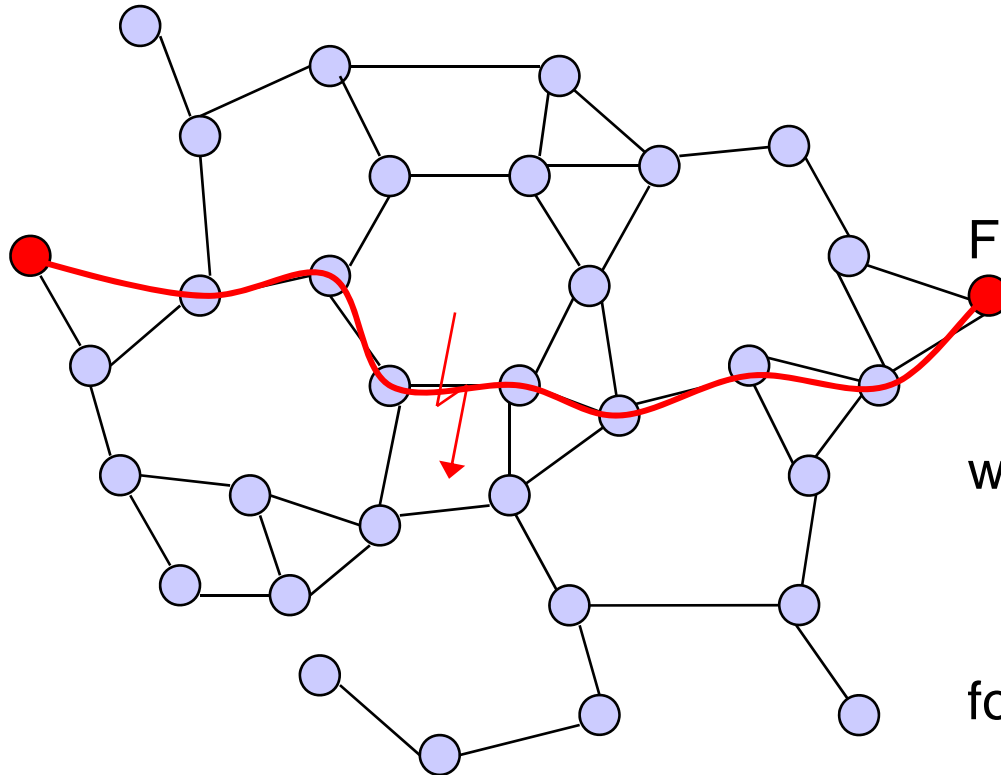
- Where to put which monitoring equipment?
- Optimality criteria

Monitoring Equipment / Failures

Failure	ME-I	ME-II	ME-III	Probability
Node				$8 \cdot 10^{-5}$
Link				$5.1 \cdot 10^{-4}$
In-Band Jamming				10^{-5}
Out-Band Jamming				10^{-5}
Time Distortion				10^{-5}
	2,200	50,000	201,100	



Good Placement



Placing ME in a way that the probability of a failure on an unmonitored link is minimal for a given path p .

For a given failure probability of

$$\phi_{p,f} = \pi_f(p) \cdot w_p$$

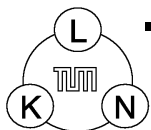
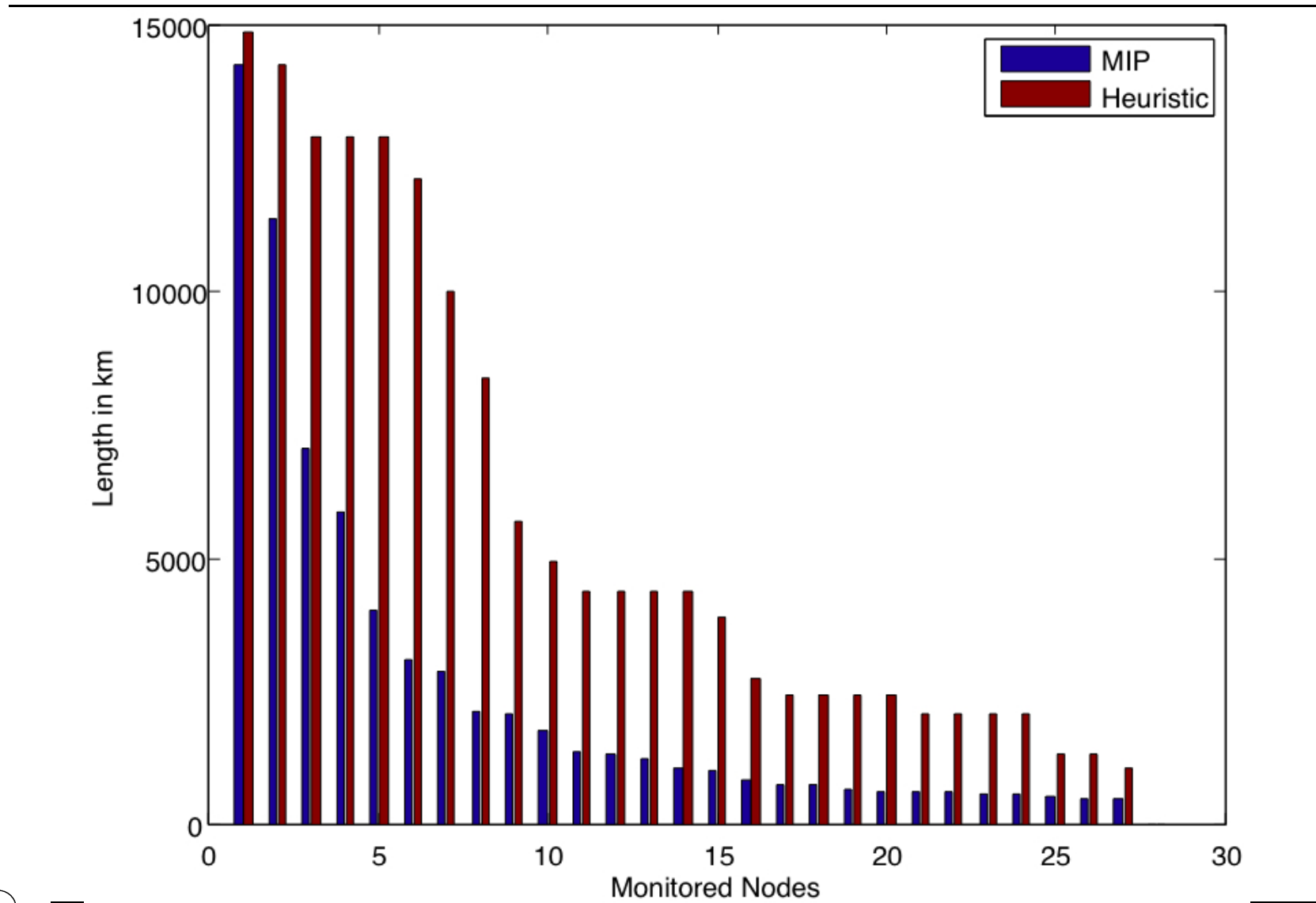
we then minimise

$$\phi_p = \sum_f (1 - m_{f,p}) \phi_{p,f}$$

for all paths.

$$\min \sum_p \phi_p$$

Why MIP?



MIP Formulation

$$\min \sum_p \phi_p$$

subject to

$$\sum_{n \in N} \left(m_{\text{ME-I},n} \cdot c_{\text{ME-I}} + \sum_{e \in E_{n,\text{in}}} m_{\text{ME-II},n,e} \cdot c_{\text{ME-II}} + m_{\text{ME-III},n} \cdot c_{\text{ME-III}} \right) \leq B$$

$$m_{\text{NL},p} \leq \sum_{\substack{n \in p \setminus \{n_1\} \\ e \in E_{n,\text{in}} \wedge e \in p}} (m_{\text{ME-I},n} + m_{\text{ME-II},n,e} + m_{\text{ME-III},n})$$

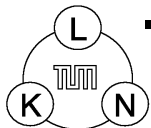
$$m_{\text{IT},p} \leq \sum_{n \in p \setminus \{n_1\}} m_{\text{ME-III},n}$$

$$m_{\text{O},p} \leq \sum_{\substack{n \in p \setminus \{n_1\} \\ e \in E_{n,\text{in}} \wedge e \in p}} (m_{\text{ME-II},n,e} + m_{\text{ME-III},n})$$

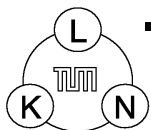
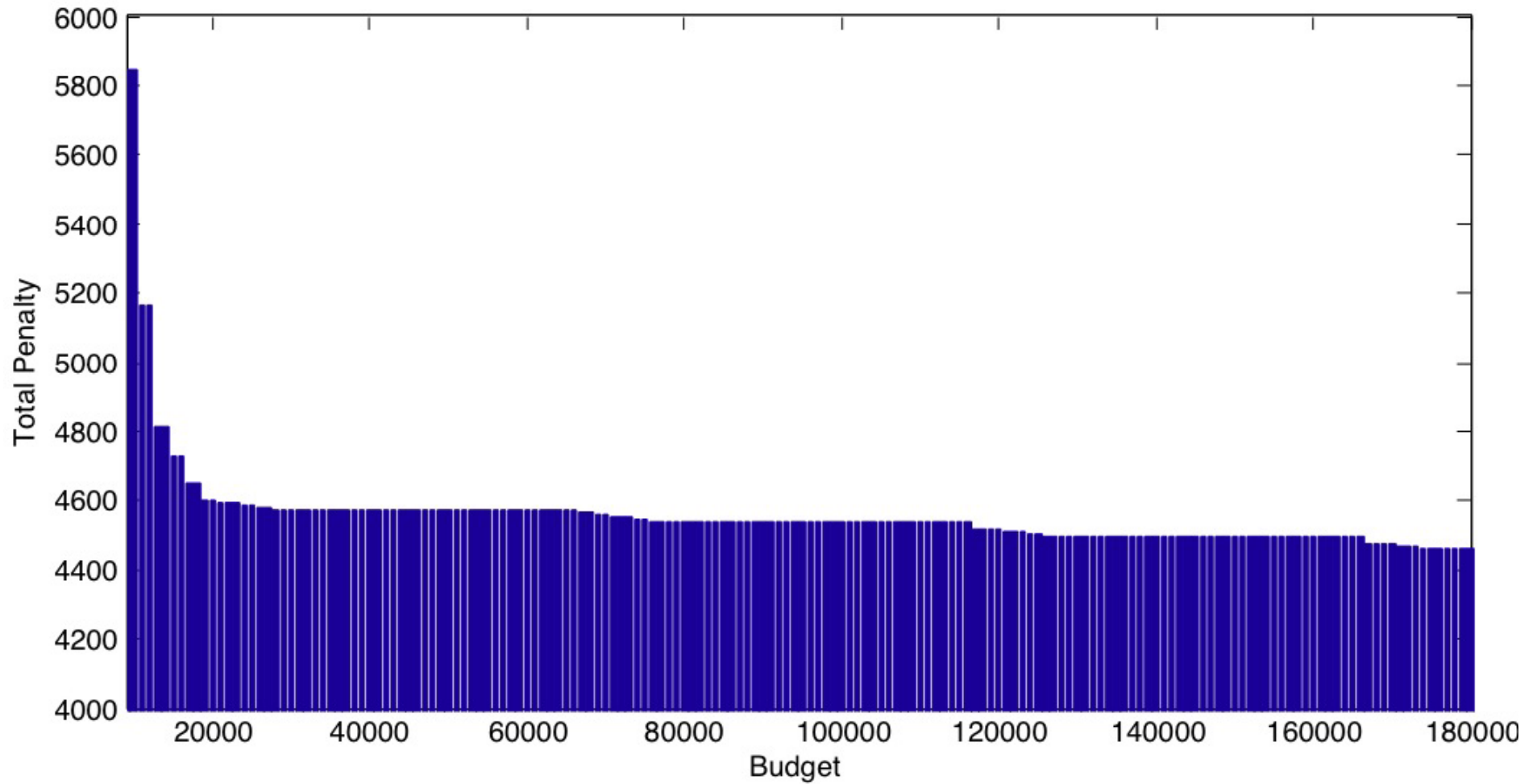
$$m_{\text{ME-I},n} + \sum_{e \in E_{n,\text{in}}} \frac{1}{|E_{n,\text{in}}|} m_{\text{ME-II},n,e} + m_{\text{ME-III},n} \leq 1$$

$$\phi_{p,f} = \pi_f(p) \cdot w_p$$

$$\phi_p = \sum_f (1 - m_{f,p}) \cdot \phi_{p,f}$$



Case Study



Conclusions

Placement of monitoring equipment

- will be an important issue in transparent optical networks
- cannot be solved by simple heuristics.

We have presented

a MIP-based solution approach feasible for typical core networks.

Although used for transparent optical networks, this approach should be applicable for other scenarios.

