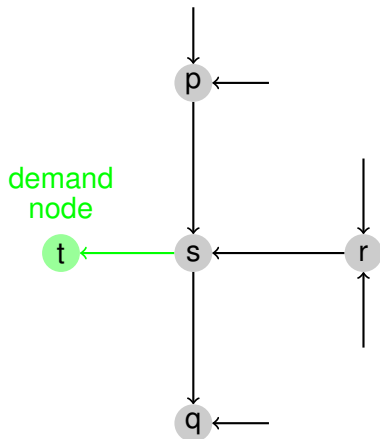


# Cutting Planes for Fixed Charge Constraints

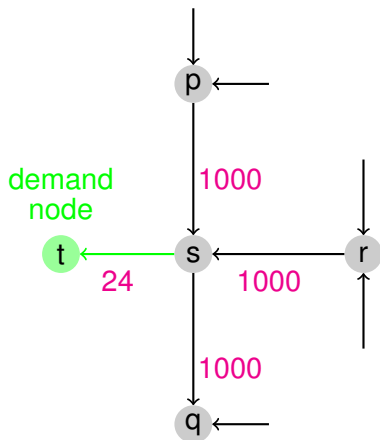


$x_e = \text{flow}, u_e = \text{capacity}$

$$\beta_e = \begin{cases} 1 & \text{if restored} \\ 0 & \text{otherwise} \end{cases}$$

$$x_e \leq \beta_e u_e$$

# Cutting Planes for Fixed Charge Constraints



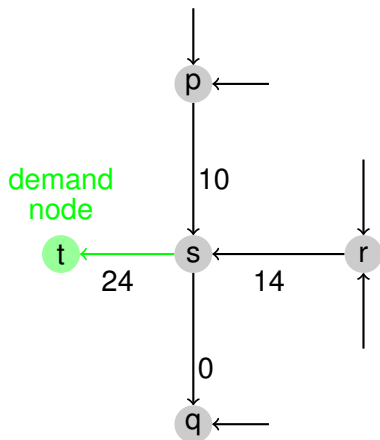
$x_e = \text{flow}$ ,  $u_e = \text{capacity}$

$$\beta_e = \begin{cases} 1 & \text{if restored} \\ 0 & \text{otherwise} \end{cases}$$

$$x_e \leq \beta_e u_e$$

Capacities  $u_e$

# Cutting Planes for Fixed Charge Constraints



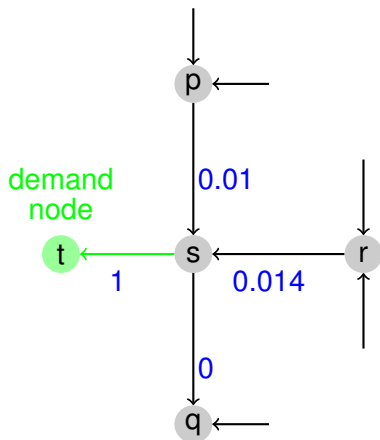
$x_e = \text{flow}, u_e = \text{capacity}$

$$\beta_e = \begin{cases} 1 & \text{if restored} \\ 0 & \text{otherwise} \end{cases}$$

$$x_e \leq \beta_e u_e$$

Flow  $x_e$  in LP solution

# Cutting Planes for Fixed Charge Constraints



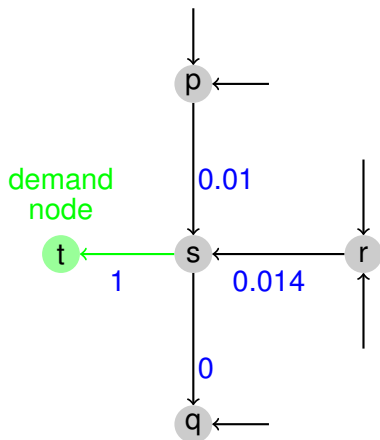
$x_e = \text{flow}, u_e = \text{capacity}$

$$\beta_e = \begin{cases} 1 & \text{if restored} \\ 0 & \text{otherwise} \end{cases}$$

$$x_e \leq \beta_e u_e$$

$\beta_e$  values in LP relaxation

# Cutting Planes for Fixed Charge Constraints



$x_e = \text{flow}, u_e = \text{capacity}$

$$\beta_e = \begin{cases} 1 & \text{if restored} \\ 0 & \text{otherwise} \end{cases}$$

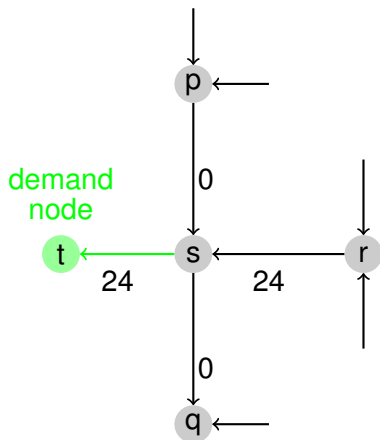
$$x_e \leq \beta_e u_e$$

$\beta_e$  values in LP relaxation

Valid constraint:

$$x_{st} \leq 24(\beta_{ps} + \beta_{rs})$$

# Cutting Planes for Fixed Charge Constraints



$x_e = \text{flow}$ ,  $u_e = \text{capacity}$

$$\beta_e = \begin{cases} 1 & \text{if restored} \\ 0 & \text{otherwise} \end{cases}$$

$$x_e \leq \beta_e u_e$$

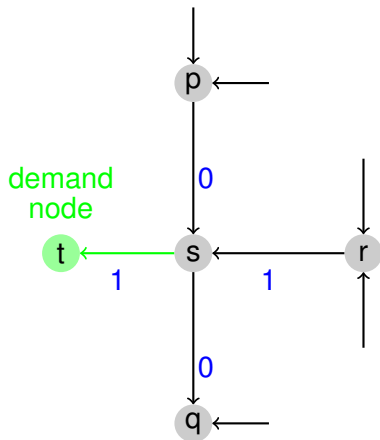
Valid constraint:

$$x_{st} \leq 24(\beta_{ps} + \beta_{rs})$$

Add constraint to LP  
relaxation

Get updated flows

# Cutting Planes for Fixed Charge Constraints



$x_e = \text{flow}$ ,  $u_e = \text{capacity}$

$$\beta_e = \begin{cases} 1 & \text{if restored} \\ 0 & \text{otherwise} \end{cases}$$

$$x_e \leq \beta_e u_e$$

Valid constraint:

$$x_{st} \leq 24(\beta_{ps} + \beta_{rs})$$

Add constraint to LP  
relaxation

Get updated  $\beta$  values:  
now integral