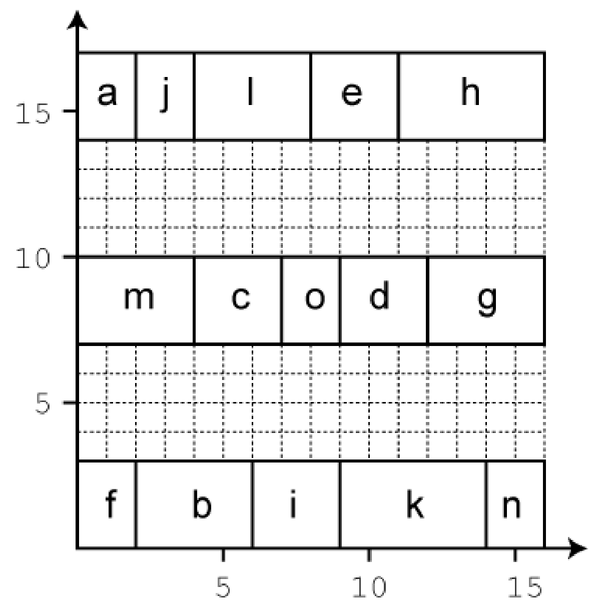
TimberWolf 7.0 Placement

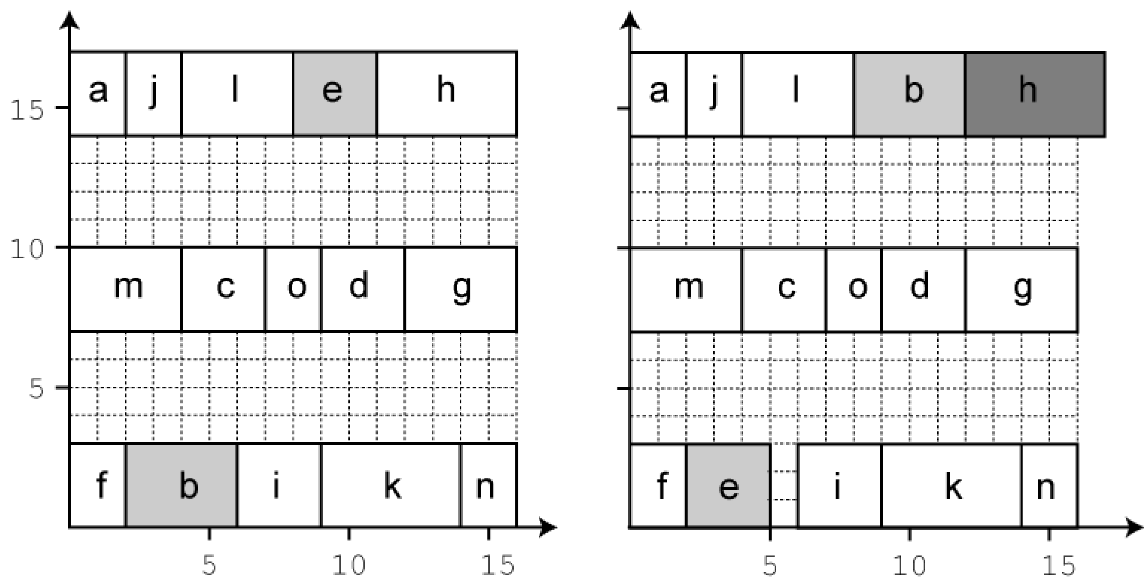
- Perform TimberWolf placement
  - Based on the given standard cell placement
  - Initial HPBB wirelength = 23

$$
\begin{aligned}
n_1 &= \{a, e, g\} \\
n_2 &= \{f, o\} \\
n_3 &= \{b, c, k, n\} \\
n_4 &= \{d, h, i\} \\
n_5 &= \{j, l, m\} \\
n_6 &= \{d, k, j\} \\
n_7 &= \{c, e, f, h, n\} \\
n_8 &= \{d, l\} \\
n_9 &= \{b, g, i, m\} \\
n_{10} &= \{a, k, o\}
\end{aligned}
$$



First Swap

- Swap node *b* and *e*
  - We shift node *h*: on the shorter side of the receiving row
  - Node *b* included in nets $\{n_3, n_9\}$, and *e* in $\{n_1, n_7\}$



(a) (b)

$$
\begin{aligned}
n_1 &= \{a, e, g\} \\
n_2 &= \{f, o\} \\
n_3 &= \{b, c, k, n\} \\
n_4 &= \{d, h, i\} \\
n_5 &= \{j, l, m\} \\
n_6 &= \{d, k, j\} \\
n_7 &= \{c, e, f, h, n\} \\
n_8 &= \{d, l\} \\
n_9 &= \{b, g, i, m\} \\
n_{10} &= \{a, k, o\}
\end{aligned}
$$

Computing ΔW

- ΔW = wirelength change from swap

Let $w(x)$ and $w'(x)$ respectively denote the wirelength before and after the swap. Then,

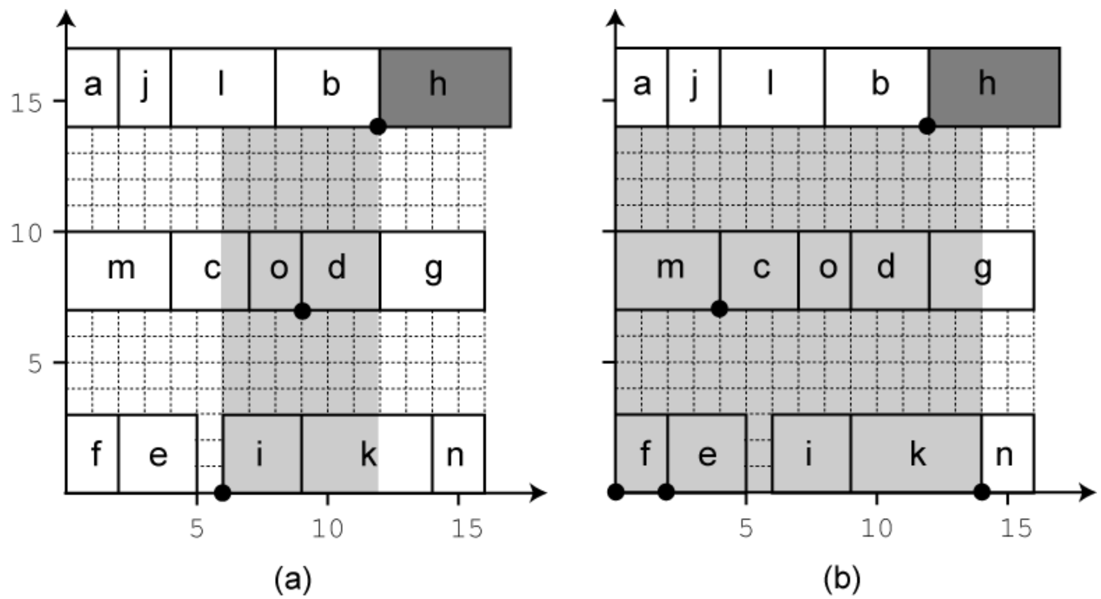
$$\Delta(n_3) = w'(n_3) - w(n_3) = 24 - 19 = 5$$
$$\Delta(n_9) = w'(n_9) - w(n_9) = 26 - 19 = 7$$
$$\Delta(n_1) = w'(n_1) - w(n_1) = 26 - 19 = 7$$
$$\Delta(n_7) = w'(n_7) - w(n_7) = 28 - 28 = 0$$

Thus,

$$\Delta W = \Delta(n_3) + \Delta(n_9) + \Delta(n_1) + \Delta(n_7) = 19$$

Estimating ΔWs

- ΔWs = wirelength change from shifting
  - h is shifted and included in $n_4 = \{d,h,i\}$ and $n_7 = \{c,e,f,h,n\}$
  - h is on the right boundary of n_4: *gradient*(h)++
  - h is not on any boundary of n_7: no further change on *gradient*(h)



Estimating ΔWs (cont)

Thus, $gradient(h) = 1$. Since h is shifted to the right by 1

$$shift\_amount(h) = 1$$

Thus,

$$\Delta W_S = gradient(h) \cdot shift\_amount(h) = 1 \cdot 1 = 1$$

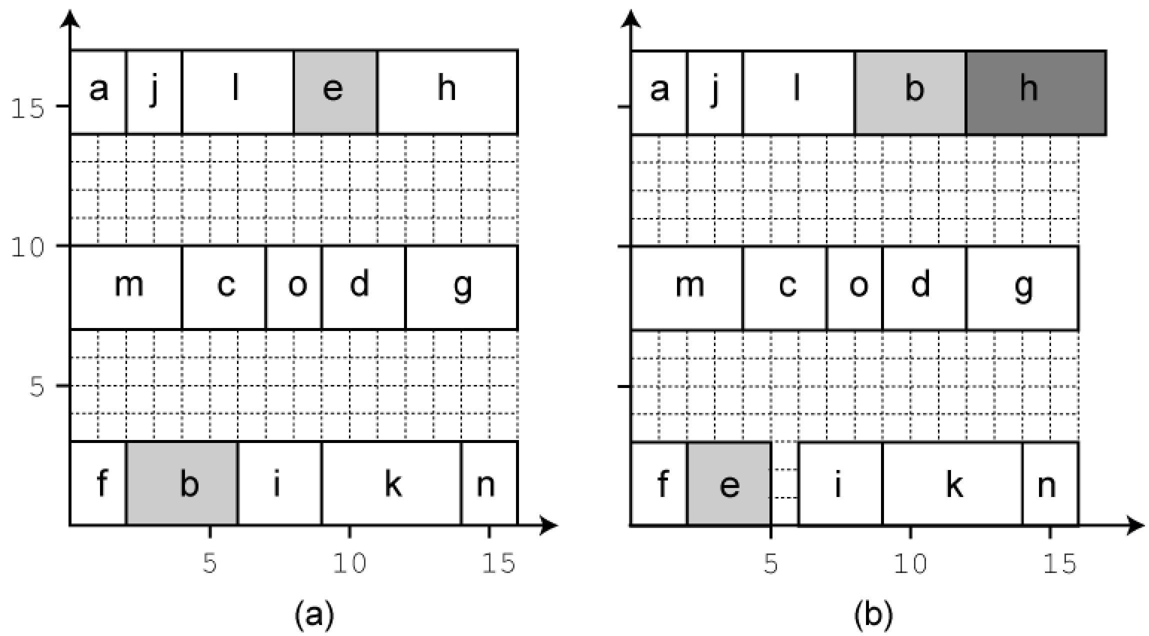
Based on the calculation of ΔW and ΔW_S, we get

$$\Delta C = \Delta W + \Delta W_S = 19 + 1 = 20$$

Accuracy of ΔWs Estimation

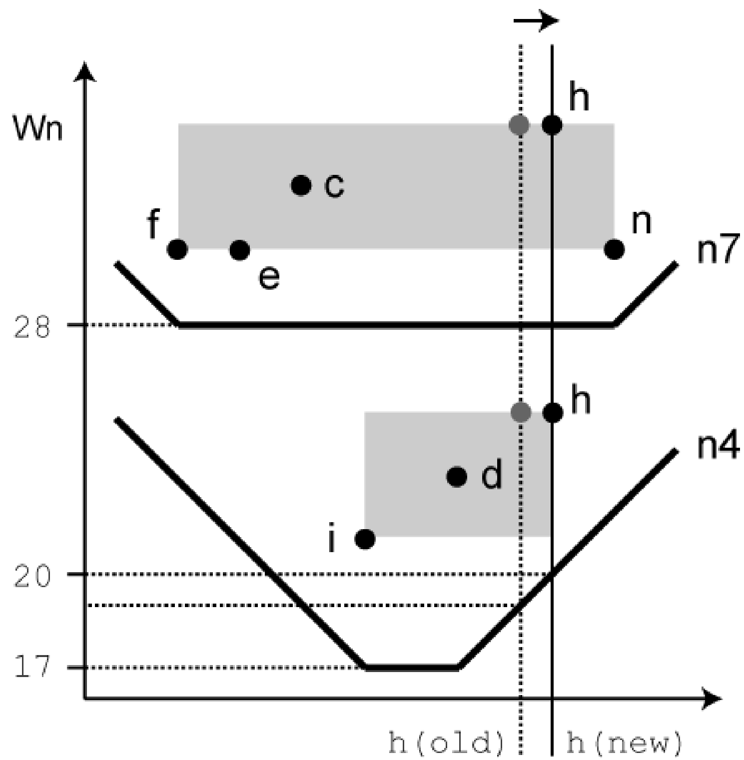
- How accurate is ΔWs estimation?
  - Node h is included in $n_4 = \{d,h,i\}$ and $n_7 = \{c,e,f,h,n\}$
  - Real change is also 1: accurate estimation

$$w'(n_4) - w(n_4) + w'(n_7) - w(n_7) = 20 - 19 + 28 - 28 = 1$$



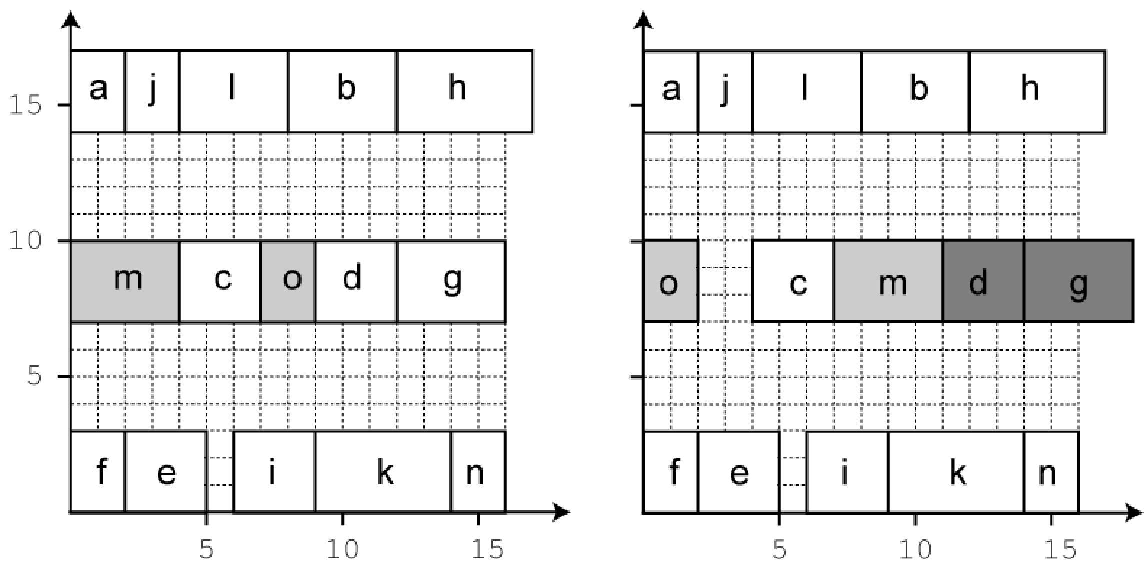
Estimation Model B

- Based on piecewise linear graph
  - Shifting h causes the wirelength of n_4 to increase by 1 (19 to 20) and no change on n_7 (stay at 28)



Second Swap

- Swap node *m* and *o*
  - We shift node *d* and *g*: on the shorter side of the receiving row
  - Node *m* included in nets $\{n_5, n_9\}$, and *o* in $\{n_2, n_{10}\}$



(a) (b)

$$
\begin{aligned}
n_1 &= \{a, e, g\} \\
n_2 &= \{f, o\} \\
n_3 &= \{b, c, k, n\} \\
n_4 &= \{d, h, i\} \\
n_5 &= \{j, l, m\} \\
n_6 &= \{d, k, j\} \\
n_7 &= \{c, e, f, h, n\} \\
n_8 &= \{d, l\} \\
n_9 &= \{b, g, i, m\} \\
n_{10} &= \{a, k, o\}
\end{aligned}
$$

Computing ΔW

- ΔW = wirelength change from swap

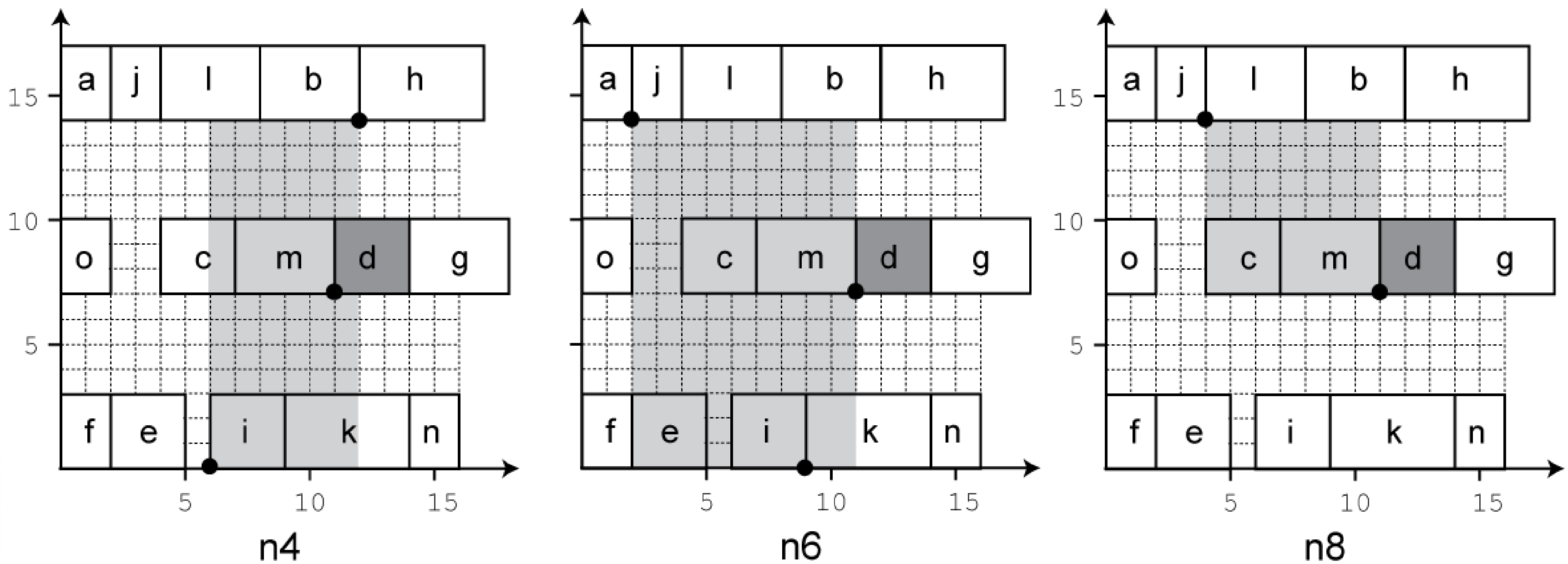
$$\Delta(n_5) = w'(n_5) - w(n_5) = 12 - 11 = 1$$
$$\Delta(n_9) = w'(n_9) - w(n_9) = 22 - 26 = -4$$
$$\Delta(n_2) = w'(n_2) - w(n_2) = 7 - 14 = -7$$
$$\Delta(n_{10}) = w'(n_{10}) - w(n_{10}) = 23 - 23 = 0$$

Thus,

$$\Delta W = \Delta(n_5) + \Delta(n_9) + \Delta(n_2) + \Delta(n_{10}) = -10$$

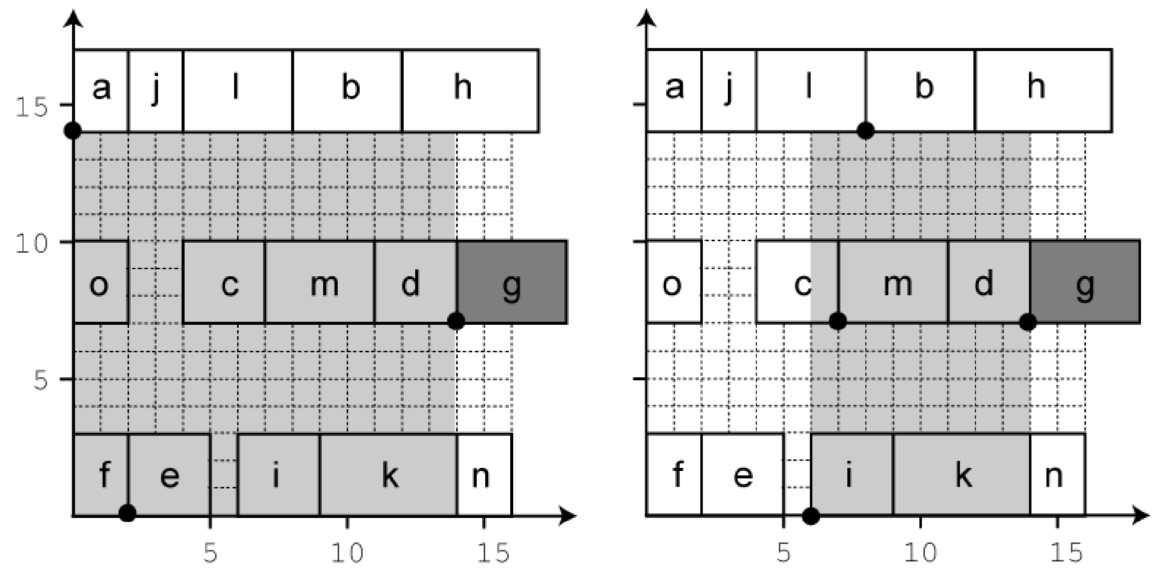
Estimating ΔWs

- Cell *d* and *g* are shifted
  - *d* is included in $n_4 = \{d,h,i\}$, $n_6 = \{d,k,j\}$, and $n_8 = \{d,l\}$
  - *d* is on the right boundary of n_6 and n_8
  - So, *gradient*(*d*) = 2



Estimating ΔWs (cont)

- Cell *d* and *g* are shifted
  - g is included in $n_1 = \{a,e,g\}$, and $n_9 = \{b,g,i,m\}$
  - g is on the right boundary of n_1 and n_9
  - So, $gradient(g) = 2$



(a) (b)

Estimating ΔWs (cont)

Both cell d and g are shifted to the right by 2. Thus,

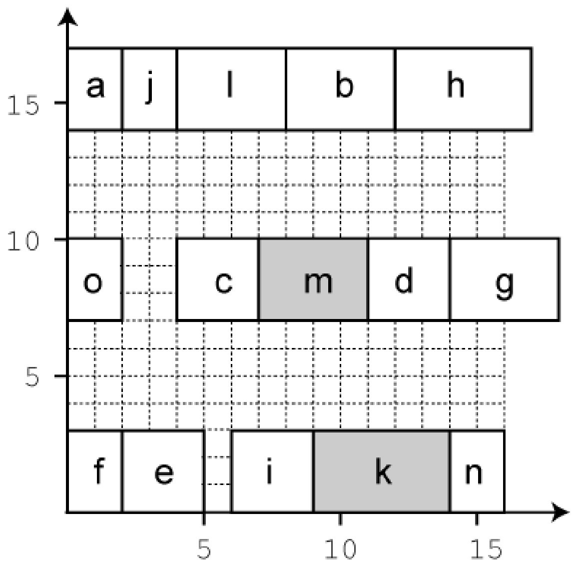
$$\begin{aligned}\Delta W_S &= gradient(d) \cdot shift\_amount(d) + \\ &\quad gradient(g) \cdot shift\_amount(g) = 2 \cdot 2 + 2 \cdot 2 = 8\end{aligned}$$

Based on the calculation of ΔW and ΔW_S, we get

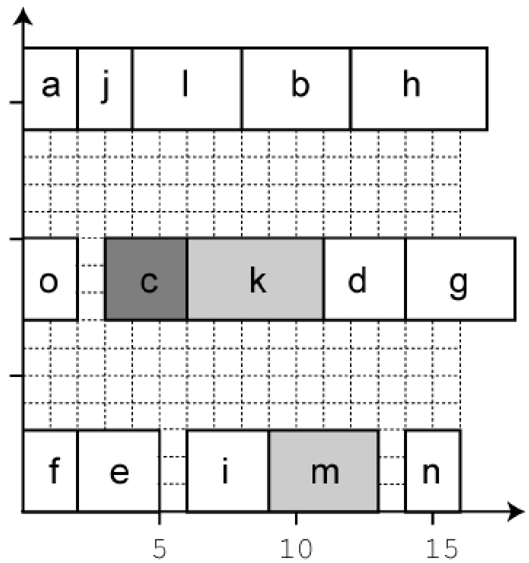
$$\Delta C = \Delta W + \Delta W_S = -10 + 8 = -2$$

Third Swap

- Swap node *k* and *m*
  - We shift node *c*: on the shorter side of the receiving row
  - Node *k* included in nets $\{n_3, n_6, n_{10}\}$, and *m* in $\{n_5, n_9\}$



(a)



(b)

$$
\begin{aligned}
n_1 &= \{a, e, g\}\\
n_2 &= \{f, o\}\\
n_3 &= \{b, c, k, n\}\\
n_4 &= \{d, h, i\}\\
n_5 &= \{j, l, m\}\\
n_6 &= \{d, k, j\}\\
n_7 &= \{c, e, f, h, n\}\\
n_8 &= \{d, l\}\\
n_9 &= \{b, g, i, m\}\\
n_{10} &= \{a, k, o\}
\end{aligned}
$$

Computing ΔW

- ΔW = wirelength change from swap

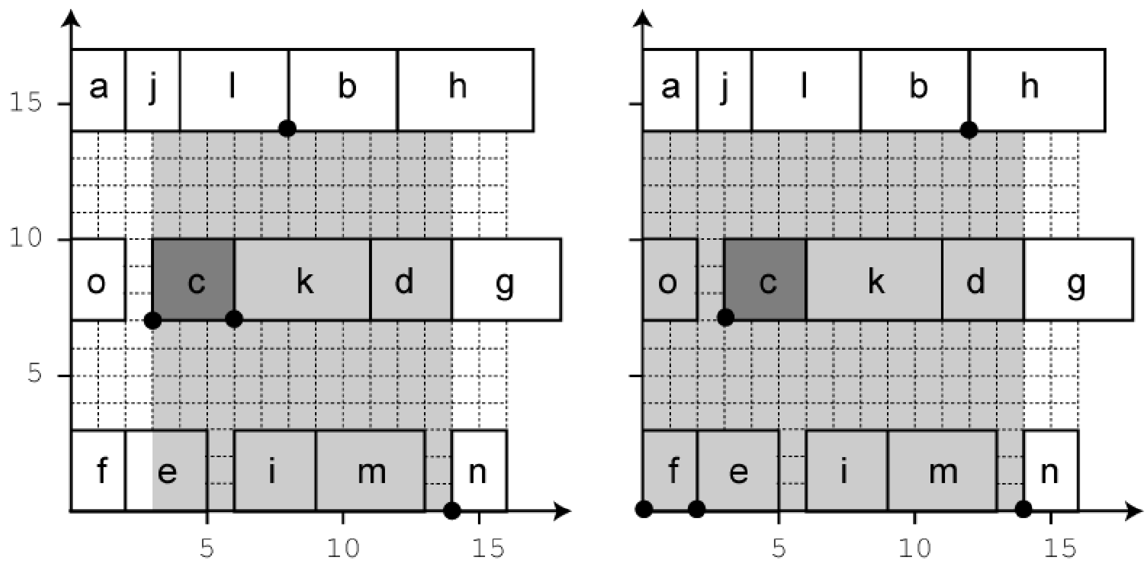
$$
\begin{aligned}
\Delta(n_3) &= w'(n_3) - w(n_3) = 25 - 24 = 1 \\
\Delta(n_6) &= w'(n_6) - w(n_6) = 16 - 23 = -7 \\
\Delta(n_{10}) &= w'(n_{10}) - w(n_{10}) = 13 - 23 = -10 \\
\Delta(n_5) &= w'(n_5) - w(n_5) = 21 - 12 = 9 \\
\Delta(n_9) &= w'(n_9) - w(n_9) = 22 - 22 = 0
\end{aligned}
$$

Thus,

$$\Delta W = \Delta(n_3) + \Delta(n_6) + \Delta(n_{10}) + \Delta(n_5) + \Delta(n_9) = -7$$

Estimating ΔWs

- Cell c is shifted
  - c is included in $n_3 = \{b,c,k,n\}$ and $n_7 = \{c,e,f,h,n\}$
  - c is on the left boundary of n_3
  - So, $gradient(c) = -1$



(a)

(b)

Estimating ΔWs (cont)

Since c is shifted to the left by 1,

$$shift\_amount(c) = -1$$

Lastly,

$$\Delta W_S = gradient(c) \cdot shift\_amount(c) = -1 \cdot -1 = 1$$

Based on the calculation of ΔW and ΔW_S, we get

$$\Delta C = \Delta W + \Delta W_S = -7 + 1 = -6$$