TULIP Algorithm Trilateration

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minRTT = propagation delay + extra delay (due to extra circular routes , congestion and router delays)

delta(T) measured= delta(t) + delta(t0)

(Pseudo-distance)

PD = delta(T) measured . alpha

(Actual distance)

D = delta(T) . alpha

PD = (delta(T) + delta(T0)). alpha

PD = D + delta(T0) .c ....(1)

D = actual distance from the landmark.

C = speed of light

alpha = X(c) i.e. Speed of digital info in fiber optic cable

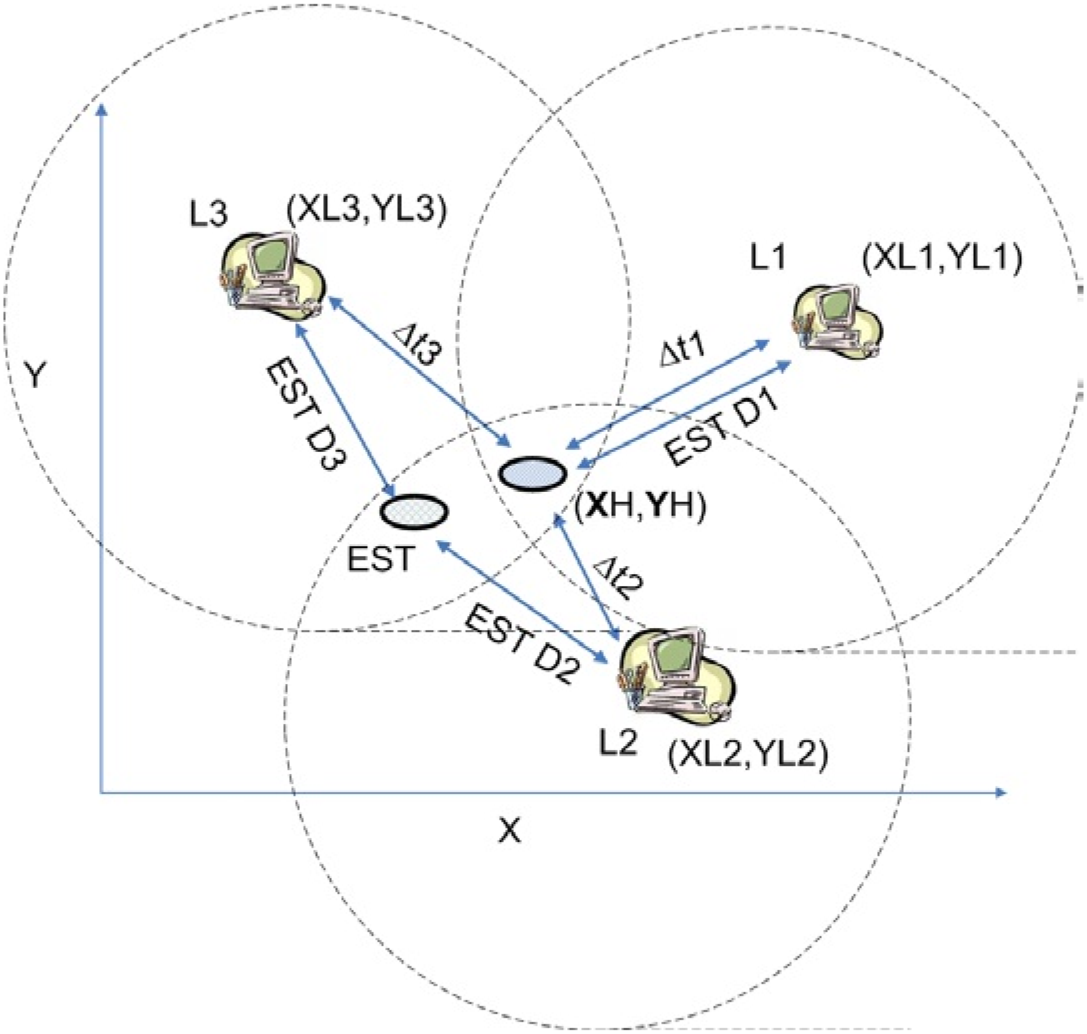
X = factor of c with which digital info travels in fiber optic cable.

delta(T) = actual propagation delay along the greater circle router/paths.

delta(T0) = the extra delay causing overestimation.

PD = pseudo distance

Graphically,



H: host
L1: Landmark 1
L2: landmark 2
L3: landmark 3

Using distance farmula:
D1= sqrt(XL1- Xh)^2 + (YL1 - YH)^2 .... (2)
FROM (1) & (2)

PD1= (sqrt(XL1 - XH)^2 + (YL1 - YH)^2) + delta(T0) . alpha .... (A)
Similarly for other 2 landmarks:
PD2= (sqrt(XL2 - XH)^2 + (YL2 - YH)^2) + delta(t0) . alpha .... (B)
PD3= (sqrt(XL3 - XH)^2 + (YL3 - YH)^2) + delta(t0) . alpha ....(C)
We need to linearize (A), (B) & (C) to solve them

Using Taylor Series:

$$f(x) = f(x0) + \frac{f(x0) . (x - x0)}{1!} + \frac{f\,'(x0) . (x - x0)}{2!}$$

Considering the simplified part first

f (x) = f (x0) + f(x0)(x - x0)

put (x-x0) = delta(x)

f (x) = f (x0) + f' (x0) delta (x) ....(3)

Hence to compute the original value of X an arbitrary value x0 is required, this is done by simple trilateration

We know that:

Hx = X est + delta (x)

Hy = Y est + delta (y)

Also

Est Di = (Lhi - Xest) + (Hy - Yest) ....(4)

From (3) and (4)

d(EstDi) . delta (x) d(EstDi) . delta(y)

PDi = Est Di + ---------- + ----------------

dX dY

After carrying out partial differentiation

(Xest - Xli) (Yest - Yi)

ODi = Est Di + ---------. delta (x) + ---------------- delta (y) + c. delta(To)
dX dY

Now we need to solve (x , y , delta(to))

$$\begin{bmatrix} PD_1 - E_{st}D_1 \\ PD_2 - E_{st}D_2 \\ PD_3 - E_{st}D_3 \end{bmatrix} = \begin{bmatrix} \frac{(X_{Est} - X_{l1})}{E_{st}D_1} & \frac{(Y_{Est} - Y_{li})}{E_{st}D_1} & c \\ \frac{(X_{Est} - X_{l2})}{E_{st}D_2} & \frac{(Y_{Est} - Y_{12})}{E_{st}D_2} & c \\ \frac{(X_{Est} - X_{l3})}{E_{st}D_3} & \frac{(Y_{Est} - Y_{13})}{E_{st}D_3} & c \end{bmatrix} \times \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta t \end{bmatrix}$$

Solution from (4) is put in eq(D) to get new estimations.

Hx,Hy becomes the new estimated position

Reference

http://www.ece.cmu.edu/research/publications/2003/CMU-ECE-2003-038.pdf