Routing Algorithm for the Highly Dynamic Network

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Dynamic Networks

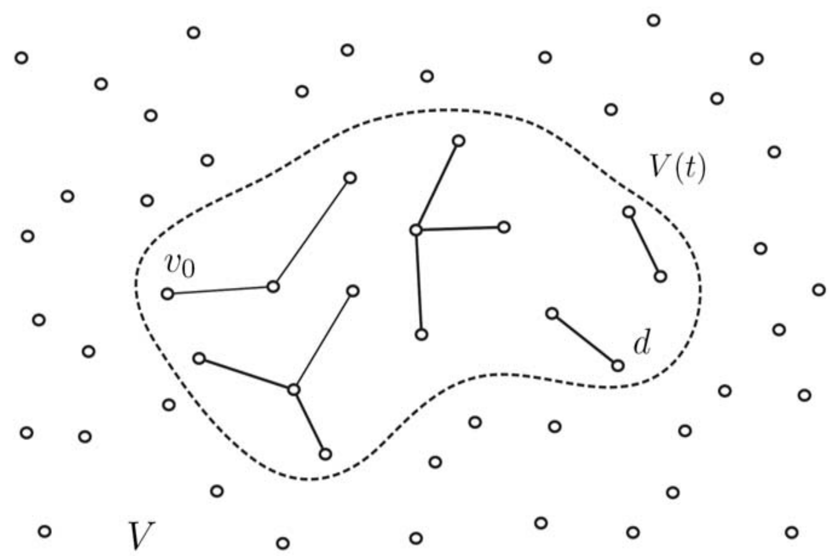
- Nodes and edges enter and leave the network
- Defined by a set of assumptions, i.e., mobility model

The Problem

- Is there a **reliable** message-passing algorithm for a highly dynamic network with node and edge mobility?
- Two general strategies for message-passing (routing, flooding)
- Despite its disadvantages, flooding is more reliable for message-passing on dynamic networks.
- The CounterFlooding [Odell & Wattenhofer 2005] algorithm works for dynamic networks with edge mobility.
  Can it be extended to the networks with node mobility?

Notations

- The dynamic graph $G(t)$ consists of dynamic nodes $V(t)$ and edges $E(t)$ with the source node denoted by v_0 and the set of all destination nodes denoted by V_d
- The total number of nodes is upper bounded by $\bar{V}$
- The set $V(t)$ contains all nodes with degree > 0
- The nodes v_1 and $v_2 \in V(t)$ are connected if a message with infinite speed from v_1 can reach v_2
- The neighboring nodes of a node v at time t is denoted by $N(v,t)$



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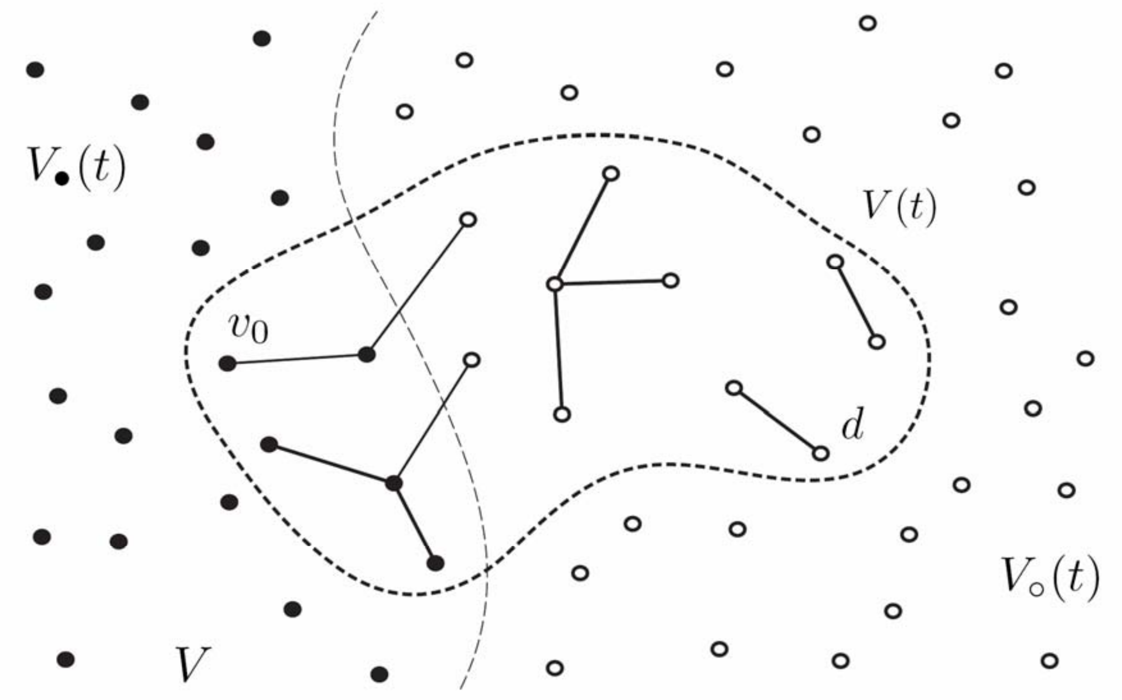


Figure 2: The sets $V_\bullet(t)$ and $V_\circ(t)$

Events

(a) The *connectivity-driven* events $c = c(v, t)$

Denote by $C_v = \{ t \mid N(v, t-\epsilon) \neq N(v, t+\epsilon) \}$ the set of all events $c(v, t)$ at a given v. Thus, C_v contains v's local vertex events. Denote by $C = \bigcup_v C_v$ the network global events. The events $c(v, 0)$ mark the "creation" of $G(t)$.

(b) The *message-driven* events $m(v, t)$ are triggered at v when a new message m from $v' \neq v$ is received. Beside nodes, messages are also network moving parts as they move between the nodes in G. Denote by M_v the set of $m(v, t)$, and M the global counterpart.

Previous assumptions

1. Edge mobility, but not node mobility, i.e., $V(t) = V$,
2. $E(t)$ is such that $G(t)$ stays connected at all time,
3. Any change $\Delta E(t)$ in $E(t)$ instantaneously triggers connectivity-driven events at all the nodes affected,
4. Adjacent nodes can pass messages in less than τ,
5. Consecutive events in C_v are separated by at least τ,
6. Nodes store the messages they receive, and
7. Nodes know the value of $\bar{V}$

HDN assumptions

1. Node and edge mobility,
2. $E(t)$ is such that each node d in V_d stays connected to at least one node v in $V_\bullet(t)$ at all time,
3. Events in C_v may be delayed from $\Delta E(t)$,
4. Adjacent nodes can pass messages in less than τ,
5. Consecutive events in C_v are separated by at least τ,
6. Nodes store the messages they receive for τ_m, and
7. Nodes know the value of $\bar{V}$

CF Algorithm

if message $m(v,t)$ is received for the first time **then**
    Broadcast message m
    $k \leftarrow 0$
end if
if event $c(v,t)$ is received **then**
    if $k < 2\bar{V}$ **then**
        Broadcast message m
        $k \leftarrow k + 1$
    end if
end if

CF works for HDN

Lemma 1 $|V_\bullet(t + 2\tau)| > |V_\bullet(t)|$ *when* $V_d \cap V_\circ(t) \neq \varnothing$.

Theorem 1 *The algorithm CF solves the HDN problem and terminates in less than* $2\,\tau\,\bar{V}$.

Proof of Lemma 1

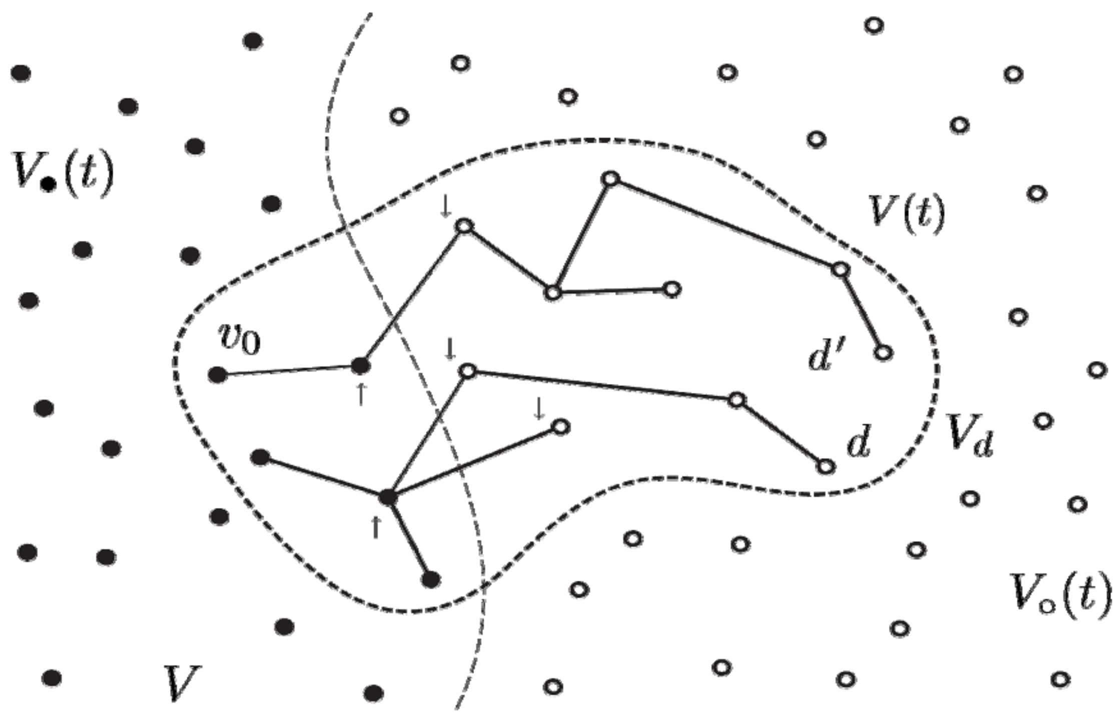


Figure 3: $V_\bullet(d,t)(\uparrow)$, $V_\circ(d,t)(\downarrow)$, $E(d,t)$, and V_d.

Proof of Lemma 1

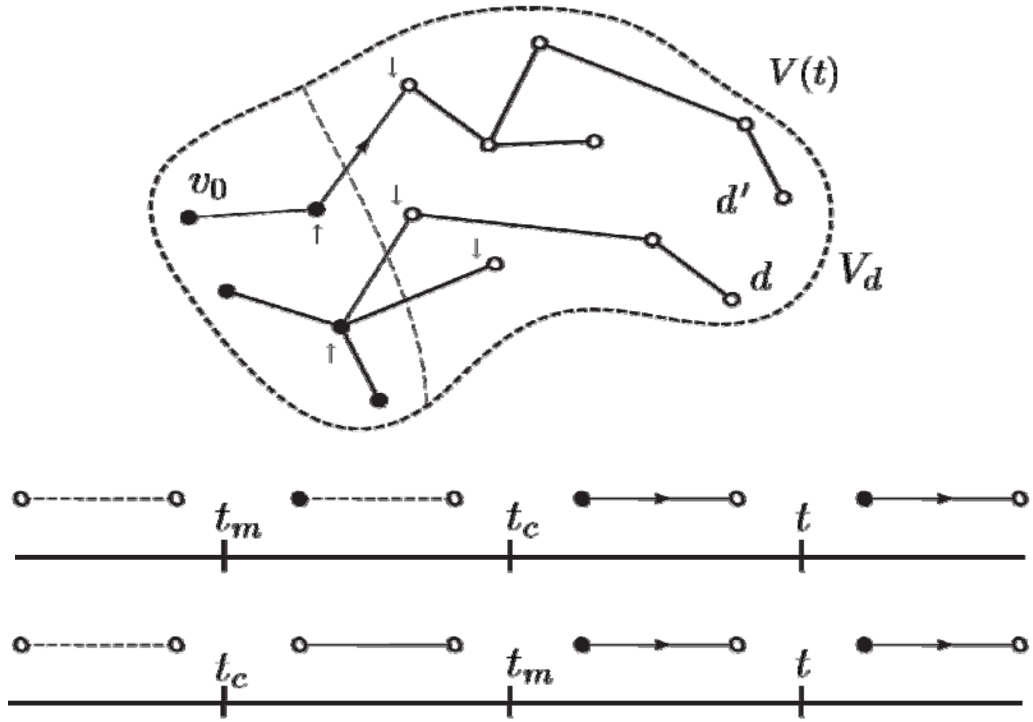
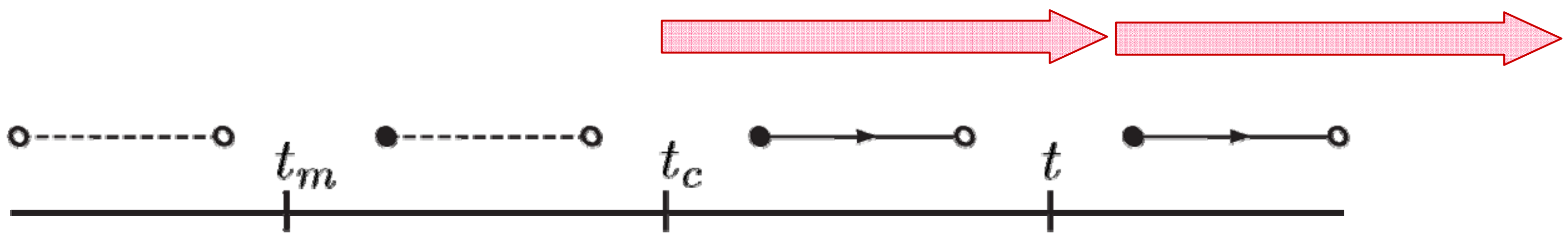


Figure 4: Two possible orders between t, t_c, and t_m

Proof of Lemma 1



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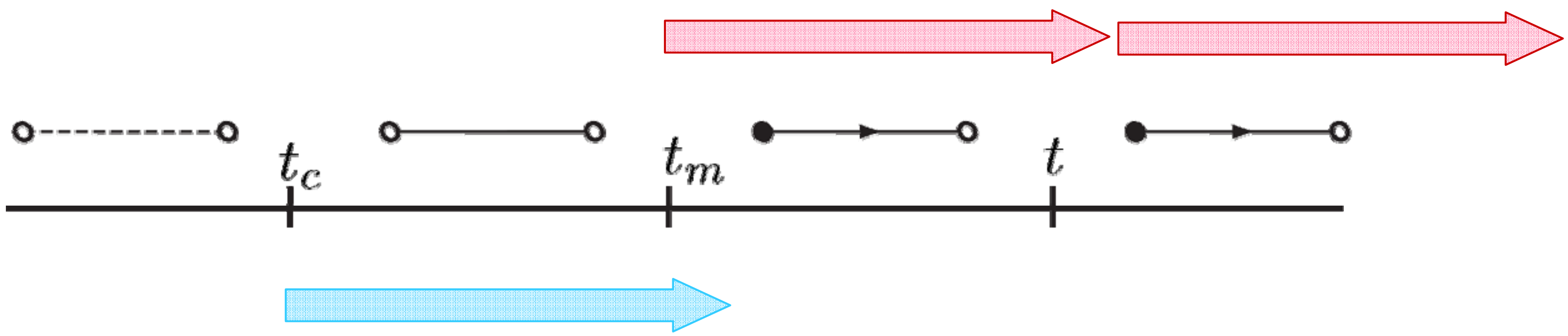

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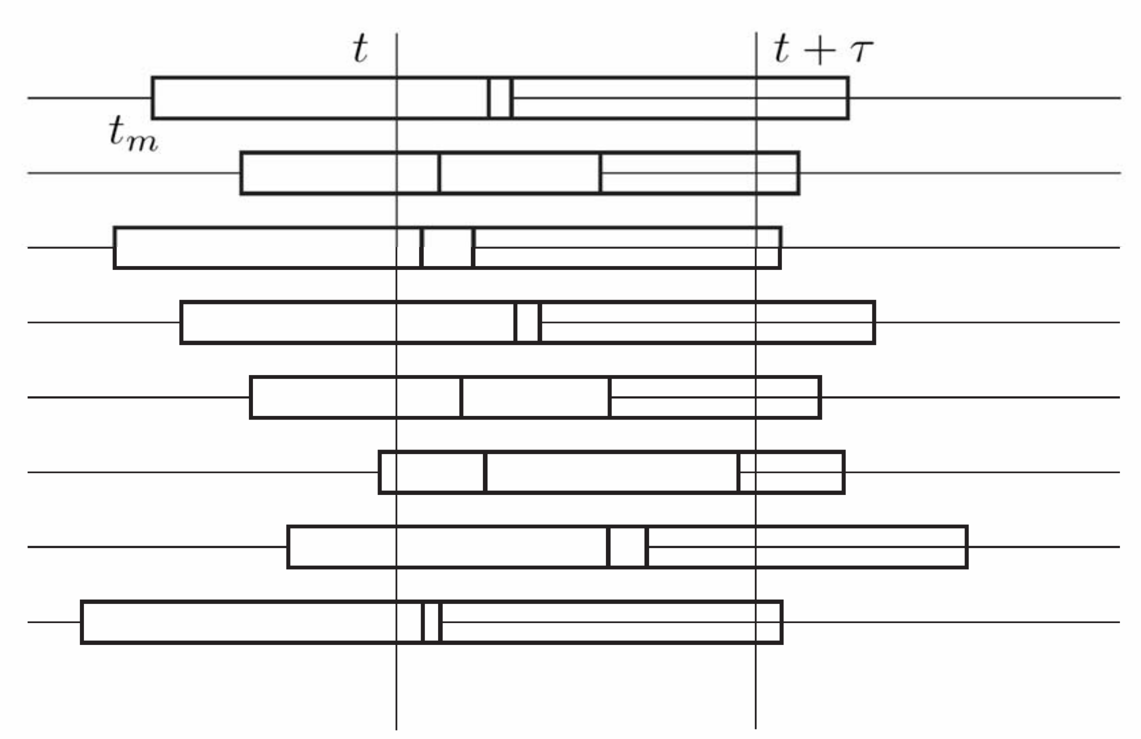

2. $E(t)$ is such that each node d in V_d stays connected to at least one node v in $V_\bullet(t)$ at all time,

Proof of Lemma 1

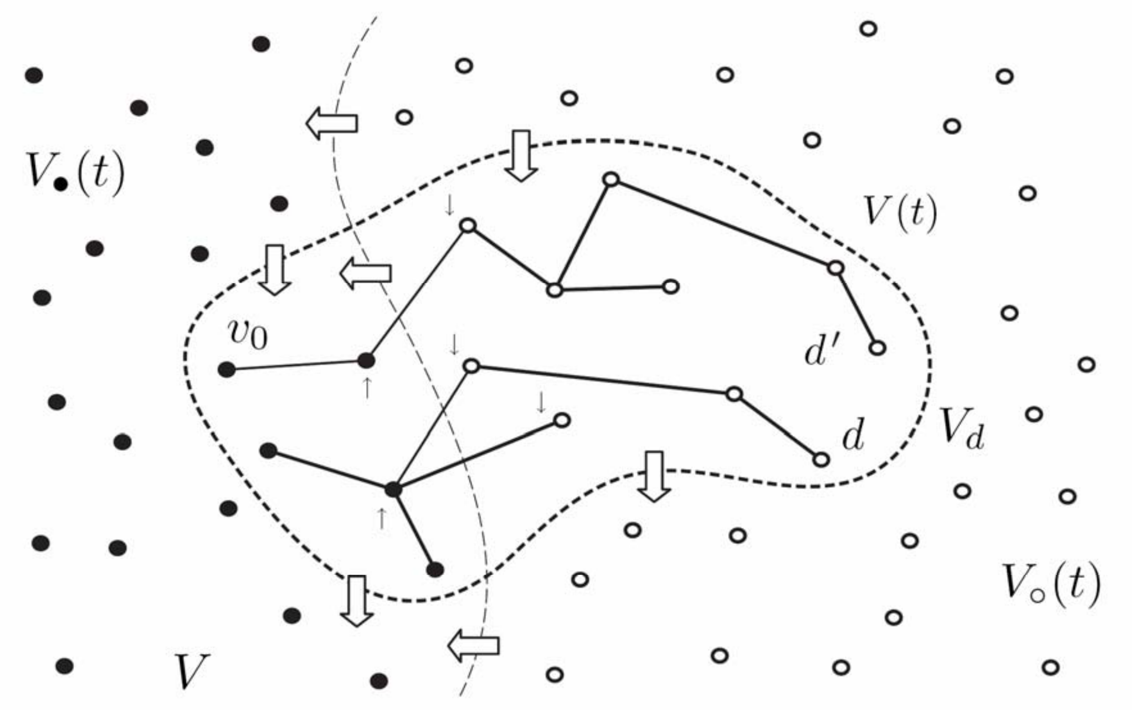

Figure 6: The arrows indicate allowable transitions of the network nodes in the sets $V_\circ(t)$, $V_\bullet(t)$, $V(t)$, and $V \backslash V(t)$ for HDN.

Proof of Theorem 1

Lemma 1 $|V_\bullet(t+2\tau)| > |V_\bullet(t)|$ *when* $V_d \cap V_\circ(t) \neq \varnothing$.

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Questions?