N2N Traffic Congestion Control for Wireless Coverage Sensor Networks

Chongdeuk Lee*
Division of Electronic Engineering, Chonbuk National University, 561-756, Korea; cdlee1008@jbnu.ac.kr

Abstract
The performance of Node-to-Node (N2N) media streaming under Wireless Coverage Sensor Networks (WCSNs) depends on congestion control reducing the sink node load. This paper proposes a new Fuzzy Logic-based N2N Traffic Congestion Control (FL-NTCC) mechanism, to efficiently control traffic congestion in wireless coverage sensor networks. The proposed FL-NTCC congestion control mechanism is an efficient strategy that enhances the routing throughput for sensor nodes, and reduces traffic congestion and the uplink bit error rate in WCSNs. The proposed mechanism uses the Fuzzy Relevance Coefficient (FRC) μ, to control N2N traffic congestion in WCSNs. The simulation results show that in comparison with the other existing mechanisms, the proposed mechanism offers better performance.

Keywords: Fuzzy Relevance Coefficient, N2N, Traffic Congestion, Uplink Bit Error, WCSNS

1. Introduction
A Wireless Coverage Sensor Network (WCSN) consists of one or more sinks and a large number of sensor nodes scattered in the coverage network application domain. In general, the wireless resource congestion from the sink to the sensor nodes is one-to-many multicast; while the uplink traffic from sensor nodes to sink node is many-to-one delivery. Due to the limited properties of wireless resources, congestion mainly occurs in the many-to-one direction. Similarly, when nodes simultaneously require the limited wireless resources to sink node, N2N traffic congestion occurs.

The N2N congestion that occurs in WCSNs has two types. The first type is node-level congestion, which is common in conventional networks. This is caused by the overuse of resources and can result in interference, and increased queuing congestion. Queuing congestion can in turn lead to retransmission, and therefore results in delay and energy consumption. The second type is link-level congestion. Link-level congestion increases the resource consumption of the sensor nodes, and decreases both link utilization, and overall throughput. Both node-level congestion and link-level congestion have direct impacts on the performance of N2N media streaming. Therefore, an efficient congestion control strategy to assure N2N media streaming in WCSNs must be presented. Several methods, such as Congestion Control and Fairness (CCF), Congestion Detection and Avoidance (CODA), and Priority-based Congestion Control Protocol (PCCP), have been proposed, to solve this problem. CCF enables the sink node to guarantee fair transmission to all sensor nodes. This method searches queues, and controls transmission rates, to avoid overflow of packets. CODA jointly uses end-to-end and hop-by-hop controls. PCCP controls congestion, using arrived packet rates. This method controls congestion, according to the priorities for arrived packet rates. Lee et al. proposed a TRM-based multimedia streaming optimization method, to improve the streaming Quality of Service (QoS), by considering minimum bandwidth, maximum bandwidth, and transmission rate in multimedia application domains. These methods are efficient in controlling congestion according to fairness and priority, but they do have the drawback of not considering the relevance degree of N2N in the uplink level.
The proposed mechanism reduces the overloads, such as the limited resource, interference, and queuing delay under a sink node. The objective of this paper is to minimize N2N traffic congestion that leads to the limited resource and higher queuing delay. The proposed N2N traffic congestion control strategy is derived to calculate the individual fuzzy relevance coefficient $\mu_{ij}$ of certain sensor nodes forwarding to the sink node. Based on the given operations, the proposed mechanism reduces the queuing delay and packet loss caused by restricted resources, and increases the throughput and streaming quality. The simulation results show that compared with the other existing mechanisms, the proposed method offers better performance.

This paper is organized as follows. Section 2 introduces the N2N Traffic Congestion Control mechanism, to improve the quality of streaming. The simulation results are presented in Section 3, and concluding remarks are provided in Section 4.

2. N2N Traffic Congestion Control Mechanism

This section describes a fuzzy logic-based N2N traffic congestion control mechanism for the wireless coverage sensor network in the sink node.

Figure 1 show the system structure for FL-NTCC in the WCSN, where the sink node can cooperatively stream from the remote sensor node and nearby peers.

2.1 Fuzzy Logic Operations

The fuzzy relevance coefficient, defined by membership function $\mu$, $\mu$ is a number in $[0, 1]$. Each member in the fuzzy relevance coefficient has a membership value defined by $\mu_{ij}$. $\phi(S)$ is the fuzzy set generated from the existing item set $S$. Each item of crisp set $S$ has the membership value in $[0, 1]$.

**Definition 1.** Fuzzy Relevance: The fuzzy set on the domain G×M has fuzzy relevance with G and M.

**Definition 2.** The Max-Min Composition of fuzzy sets: Let P(X, Y) be the fuzzy relation of X and Y, and P(Y, Z) be the fuzzy relation of Y and Z. Then, the Max-Min combination for P(X, Y) and Q(Y, Z) is $\mu_{x \in X} \cap \mu_{y \in Y} \cup \mu_{z \in Z} \{\mu_x(x, y), \mu_y(y, z)\}$

where, the Max-Min combination represents the relationship between sets X and Z.

**Definition 3.** For finite set $X = \{x_1, x_2, ..., x_n\}$, fuzzy set $A$ is defined by $A = \mu_a(x_i) / x_i + \mu_a(x_i) / x_i + ... + \mu_a(x_i) = \sum_{i=1}^{n} \mu_a(x_i) / x_i$, where “+” means the “OR” operation.

2.2 N2N Traffic Congestion Detection

This section considers N2N links sharing uplink channel bandwidth between a sink and sensor nodes (SN). The total uplink traffic resource for streaming media data is assumed to be divided into $N$ coverage resource blocks (CRB). At a given time slot $t$, the CRB can be indexed as $(t, CR)$, where CR is a coverage resource, $CR \in \{1, ..., N\}$. Presuming N2N links and (SN) uplink sharing $(t, CR)$, co-channel congestion degrades the throughput and link utilization for media data streaming.

Figure 2 represents the traffic explosion caused by channel bandwidth, when N2N links are $(p, k)$, and an uplink SN transmitting in the same CRB. Here, the N2N pair $k$ consists of an N2N transmitter $N(t, k)$, and an N2N...
The channel bandwidth from $B_r$ to $SN$ is defined as in Equation (3).

$T_{con}(i) = \frac{(T - \bar{T}) \sum_{x \in S} (S(x) - S(x_j))}{N_{r,cb}(i) + CI(i)} \times \lambda \quad (4)$

Where, $\bar{T}$ is the duration from SNs to sink. $\lambda (0 < \lambda < 1)$ is the encoding rate, and $S(x)$ is a media object size.

Generally, it is not easy to detect uplink congestion. In this paper, we consider the channel interference, encoding rate, and media object size, to efficiently detect the traffic congestion for $SN_i$.

### 2.3 Uplink Traffic Congestion Control Operations

This section describes an efficient uplink traffic congestion control operations for media objects transmitting by $SN_i$. For restrictions $c$ and $c' \in C$, the control mapping operations are defined as follows.

#### 2.3.1 Congestion Control by Disjunction Mapping

The disjunction ($\cup$) mapping operation controls media objects with Min-Max relation, considering the cache capacity, and the size of objects. $M^\cup_{disjunction}$ and $M_{disjunction}$ consider the cache capacity, and the size of media objects in the sink, respectively. The disjunction mapping operation ($\cup$) is defined as the following.

**Definition 4.** $M^\cup_{disjunction}: \forall c, c' \in C, c is c \cup c' \in C$ is the cache capacity, and $s$ is the size of media objects.

#### 2.3.2 Congestion Control by Conjunction Mapping

The Conjunction mapping operation ($\cap$), considering the capacity of the cache, the size of objects, and fuzzy relevance coefficient $\mu$, is to control objects with Min-Max relationship. $M^\cap_{conjunction}$, $M_{conjunction}$, and $M^\mu_{conjunction}$ consider the capacity of the cache, the size of objects, and the fuzzy relevance coefficient $\mu$, respectively. The conjunction mapping operation is defined as the following.
Definition 5. \( M_{\text{conjunction}}^{(C,C')\cap\mu} : c \cap c' \in C, \ \forall c, c' \in C \)
where, \( \forall c, c' \in C \), and \( \emptyset \) is null.

2.3.3 Congestion Control by Filtering Mapping

Filtering mapping is used to control media objects that do not satisfy disjunction mapping \((\cup)\), or conjunction mapping \((\cap)\). Filtering mapping, which is performed by disjunction mapping and conjunction mapping, is denoted by \( M_{\text{filtering}}^{\mu} \) for \( f_i \in F \), and defined as follows.

Definition 6.

\[
M_{\text{filtering}}^{\mu} = \{ M_{\text{filtering}}^{\mu}(O) \mid \text{Max}\{\lambda \leq \mu(SN_i) \text{ and } \mu(SN_j) \geq 0.6\}
\]
where, \( \mu(SN_j) \geq 0.6 \) is media objects larger than 0.6.

3. Simulation Results

To measure the performance, we considered the following simulation parameters: the bit rate is 1.5 Mbps, the data packet size for the streaming is 512 k byte, and the network size is \((0,0) \times (250, 250)\). The other parameters are as follows: the link bandwidth is 10/100 Mbps, and the average link bandwidth is 1.2 Mbps. The simulation continues for 560 s with \( 0 < \lambda < 1 \), and the time stamp of \((T - \hat{T})\) and \((\hat{T} - T)\) sets 0.2 s.

Table 2 summarizes the simulation result for FL-NTCC and non-FL-NTCC. Non-FL-NTCC has lower performance than FL-NTCC indices, in throughput, packet loss rate, queuing delay rate, congestion control rate, and latency rate. As shown in Table 2, the throughput of the proposed FL-NTCC is improved by about \( \frac{1}{2} \), over that for Non-FL-NTCC.

We simulated changing the fuzzy relevance coefficient \( \mu \) and the media object size. Major metrics used in the simulation are the average traffic congestion control rate, and the throughput. The proposed method is compared and analyzed with the other existing schemes: CCF\(^2\), PCCP\(^6\) and TRM\(^5\).

Table 2. Simulation Results

<table>
<thead>
<tr>
<th>Performance</th>
<th>Non FL-NTCC (%)</th>
<th>FL-NTCC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput</td>
<td>66.2</td>
<td>99.7</td>
</tr>
<tr>
<td>Packet loss rate</td>
<td>5.3</td>
<td>0.021</td>
</tr>
<tr>
<td>Queuing delay rate</td>
<td>8.4</td>
<td>0.017</td>
</tr>
<tr>
<td>Congestion control rate</td>
<td>72.5</td>
<td>99.4</td>
</tr>
<tr>
<td>Latency rate</td>
<td>11.3</td>
<td>0.027</td>
</tr>
</tbody>
</table>

Figure 3(a) and (b) The average traffic congestion control rate and throughput with the fuzzy relevance coefficient \( \mu \).

Figure 3(a) and Figure 3(b) show the performance of the average traffic congestion control rate, and the throughput, when the fuzzy relevance coefficient \( \mu \) is 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9.

As shown in Figures 3 (a) and (b), when the fuzzy relevance coefficient \( \mu \) is higher, the proposed method achieves better performance than the other methods.
Figures 4 (a) and (b) show the performance of the average traffic congestion control rate and throughput, when the media object size is 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 Mbyte.

As shown in Figures 4 (a) and (b), when the media object size is larger, the proposed method efficiently controls the traffic congestion, and improves throughput. We have found that the system performance by the fuzzy relevance coefficient is proportional to the result of the average traffic congestion control and the average throughput. This result is because the proposed method applied the sink congestion $S_{CON}(i)$ and the traffic congestion $T_{CON}(i)$ for $SN_{CB}(k)$, $SN_{B}(i)$, and $SN_{t}(j)$, and uplink traffic congestion control mapping operations for media objects. The proposed method showed that it is not influenced by the channel interference, encoding rate, cache capacity, or media object size. Hence, the proposed method efficiently controls the traffic congestion, and N2N media services are maintained in a stable state.

4. Conclusion

In recent years, several new congestion algorithms have been proposed for WCSNs. This paper proposed a new Fuzzy Logic-based N2N Traffic Congestion Control (FL-NTCC) mechanism, to provide high-quality N2N media service among sensor nodes in WCSNs. In WCSNs, a sink monitors media objects and stream packets received from sensor nodes. In WCSNs, we applied the fuzzy relevance coefficient $\mu$ and encoding rate $\lambda$, to reduce the channel interference and traffic congestion caused by uplink. For more careful control of traffic congestion, we performed uplink traffic congestion control mapping operations for media objects. The results show that the proposed mechanism controlled the N2N traffic congestion in a stable state.

5. Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education (No.2013R1A1A4A01005033).

6. References

