GPU Acceleration of Volumetric Rendering in Path Tracing

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Multifrequency media access control has been well understood in general wireless ad hoc networks, while in wireless sensor networks, researchers still focus on single frequency solutions. In wireless sensor networks, each device is typically equipped with a single radio transceiver and applications adopt much smaller packet sizes compared to those in general wireless ad hoc networks. Hence, the multifrequency MAC protocols proposed for general wireless ad hoc networks are not suitable for wireless sensor network applications, which we further demonstrate through our simulation experiments. In this article, we propose MMSN, which takes advantage of multifrequency availability while, at the same time, takes into consideration the restrictions of wireless sensor networks. Through extensive experiments, MMSN exhibits the prominent ability to utilize parallel transmissions among neighboring nodes. When multiple physical frequencies are available, it also achieves increased energy efficiency, demonstrating the ability to work against radio interference and the tolerance to a wide range of measured time synchronization errors.

CCS Concepts: • **Computing methodologies → Ray tracing**; *Real-time simulation*; *Interactive simulation*; *Massively parallel and high-performance simulations*;

Additional Key Words and Phrases: rendering, ray-tracing, path-tracing, volume rendering, participating media

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1 INTRODUCTION

This is a test using the ACM SIGGRAPH TEMPLATE in Latex. This file is using the acmtog aticle type. Most of the content is still from the template and will be updated for the final submission

2 MMSN PROTOCOL

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2.1 Frequency Assignment

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This is a numbered equation:

$$P(t) = \frac{b^{\frac{t+1}{T+1}} - b^{\frac{t}{T+1}}}{b-1}, \tag{1}$$

where $t = 0, \ldots, T$, and b is a number greater than 1.

In our algorithm, we use the suboptimal approach for simplicity and generality. We need to make the distribution of the selected back-off time slice at each node conform to what is shown in Equation (1). It is implemented as follows: First, a random variable α with a uniform distribution within the interval $(0, 1)$ is generated on each node, then time slice i is selected according to the following equation:

$$i = \lfloor (T+1) \log_b [\alpha(b-1)+1] \rfloor.$$

It can be easily proven that the distribution of i conforms to Equation (1).

So protocols [1–6] that use RTS/CTS controls[1] for frequency negotiation and reservation are not suitable for WSN applications, even though they exhibit good performance in general wireless ad hoc networks.

2.1.1 *Exclusive Frequency Assignment.*

In exclusive frequency assignment, nodes first exchange their IDs among two communication hops so that each node knows its two-hop neighbors' IDs. In the second broadcast, each node beacons all neighbors' IDs it has collected during the first broadcast period.

Eavesdropping. Even though the even selection scheme leads to even sharing of available frequencies among any two-hop neighborhood, it involves a number of two-hop broadcasts. To reduce the communication cost, we propose a lightweight eavesdropping scheme.

2.2 Basic Notations

As Algorithm 1 states, for each frequency number, each node calculates a random number (Rnd_α) for itself and a random number (Rnd_β) for each of its two-hop neighbors with the same pseudorandom number generator.

Bus masters are divided into two disjoint sets, $\mathcal{M}_{RT}$ and $\mathcal{M}_{NRT}$.

RT Masters $\mathcal{M}_{RT} = \{\vec{m}_1, \ldots, \vec{m}_n\}$ denotes the n RT masters issuing real-time constrained requests. To model the current request issued by an $\vec{m}_i$ in $\mathcal{M}_{RT}$, three parameters—the recurrence time (r_i), the service cycle (c_i), and the relative deadline (d_i)—are used, with their relationships.

NRT Masters $\mathcal{M}_{NRT} = \{\vec{m}_{n+1}, \ldots, \vec{m}_{n+m}\}$ is a set of m masters issuing nonreal-time constrained requests. In our model, each $\vec{m}_j$ in $\mathcal{M}_{NRT}$ needs only one parameter, the service cycle, to model the current request it issues.

Here, a question may arise, since each node has a global ID. Why don't we just map nodes' IDs within two hops into a group of frequency numbers and assign those numbers to all nodes within two hops?

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[1]RTS/CTS controls are required to be implemented by 802.11-compliant devices. They can be used as an optional mechanism to avoid Hidden Terminal Problems in the 802.11 standard and protocols based on those similar to [2] and [1].

ALGORITHM 1: Frequency Number Computation

Input: Node α's ID (ID_α), and node α's neighbors' IDs within two communication hops.
Output: The frequency number ($FreNum_\alpha$) node α gets assigned.
$index$ = 0; $FreNum_\alpha$ = -1;
repeat
  Rnd_α = Random(ID_α, $index$);
  $Found$ = $TRUE$;
  for *each node β in α's two communication hops* **do**
    Rnd_β = Random(ID_β, $index$);
    if *($Rnd_\alpha < Rnd_\beta$) or ($Rnd_\alpha == Rnd_\beta$ and $ID_\alpha < ID_\beta$);*
    then
      $Found$ = $FALSE$; break;
    end
  end
  if $Found$ **then**
    $FreNum_\alpha$ = $index$;
  else
    $index$ ++;
  end
until $FreNum_\alpha > -1$;

Fig. 1. Code before preprocessing.

3 SIMULATOR

If the model checker requests successors of a state which are not created yet, the state space uses the simulator to create the successors on-the-fly. To create successor states the simulator conducts the following steps.

(1) Load state into microcontroller model.
(2) Determine assignments needed for resolving nondeterminism.
(3) For each assignment.
  (a) either call interrupt handler or simulate effect of next instruction, or
  (b) evaluate truth values of atomic propositions.
(4) Return resulting states.

Figure 1 shows a typical microcontroller C program that controls an automotive power window lift. The program is one of the programs used in the case study described in Section 3. At first sight, the programs looks like an ANSI C program. It contains function calls, assignments, if clauses, and while loops.

3.1 Problem Formulation

The objective of variable coalescence-based offset assignment is to find both the coalescence scheme and the MWPC on the coalesced graph. We start with a few definitions and lemmas for variable coalescence.

Definition 3.1 (Coalesced Node (C-Node)). A C-node is a set of live ranges (webs) in the AG or IG that are coalesced. Nodes within the same C-node cannot interfere with each other on the IG. Before any coalescing is done, each live range is a C-node by itself.

Table 1. Simulation Configuration

TERRAIN[a]	(200m×200m) Square
Node Number	289
Node Placement	Uniform
Application	Many-to-Many/Gossip CBR Streams
Payload Size	32 bytes
Routing Layer	GF
MAC Layer	CSMA/MMSN
Radio Layer	RADIO-ACCNOISE
Radio Bandwidth	250Kbps
Radio Range	20m–45m

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[a]This is a table footnote. This is a table footnote. This is a table footnote.

Definition 3.2 (C-AG (Coalesced Access Graph)). The C-AG is the access graph after node coalescence, which is composed of all C-nodes and C-edges.

LEMMA 3.3. *The C-MWPC problem is NP-complete.*

PROOF. C-MWPC can be easily reduced to the MWPC problem assuming a coalescence graph without any edge or a fully connected interference graph. Therefore, each C-node is an uncoalesced live range after value separation and C-PC is equivalent to PC. A fully connected interference graph is made possible when all live ranges interfere with each other. Thus, the C-MWPC problem is NP-complete. □

LEMMA 3.4 (LEMMA SUBHEAD). *The solution to the C-MWPC problem is no worse than the solution to the MWPC.*

PROOF. Simply, any solution to the MWPC is also a solution to the C-MWPC. But some solutions to C-MWPC may not apply to the MWPC (if any coalescing were made). □

4 PERFORMANCE EVALUATION

During all the experiments, the Geographic Forwarding (GF) by Akuilidz et al. [2] routing protocol is used. GF exploits geographic information of nodes and conducts local data-forwarding to achieve end-to-end routing. Our simulation is configured according to the settings in Table 1. Each run lasts for 2 minutes and repeated 100 times. For each data value we present in the results, we also give its 90% confidence interval.

5 CONCLUSIONS

To be added later

A FIRST SECTION

To be added later

B SUPPLEMENTARY MATERIALS

To be added later

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